Systems Approaches to Public Service Delivery:

Methods and Frameworks

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Abstract

Researchers and practitioners are increasingly embracing *systems approaches* to deal with the complexity of public service delivery and policy evaluation. However, the diversity of these methods and their lack of common theoretical grounding has limited constructive engagement between those working within the systems tradition and those working outside it. We address this by reviewing and critically synthesizing systems literature from the fields of health, education, and infrastructure. We argue that the common theoretical core of systems approaches is the idea that *multi-dimensional complementarities* between a policy and other aspects of the policy context are the first-order problem of policy design and evaluation. What differentiates systems approaches from other research traditions is thus not so much a specific method as a general difference in question prioritization, and consequently greater methodological pluralism. We distinguish between *macro-systems* approaches, which focus on the collective coherence of a set of policies or institutions, and *micro-systems* approaches, which focus on how a single policy interacts with the context in which it operates. We develop a typology of micro-systems approaches and their relationship to standard impact evaluation methods, and discuss their relationship to adjacent concepts such as external validity, implementation science, and complexity theory.

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1. Introduction

Across the social sciences, researchers and practitioners working to use evidence to improve public service delivery are increasingly turning to *systems approaches* to remedy what they see as the limitations of traditional approaches to policy evaluation. This includes increasing calls from disciplines like economics and management to adopt systems approaches to understanding the complexities of government bureaucracies (Pritchett, 2015; Bandiera et al., 2019; Besley et al., 2022). While those turning to systems approaches are united in viewing standard impact evaluation methods (at least in their more naïve applications) as overly simplistic, deterministic, and insensitive to context, the alternative methods they have developed are hugely varied. Studies that self-identify as systems approaches include everything from ethnographic approaches to understanding citizen engagement with public health campaigns during the 2014 Ebola outbreak in West Africa (Martineau, 2016) to high-level World Health Organization frameworks (De Savigny and Adam, 2009), multi-sectoral computational models of infrastructure systems (e.g. Saidi et al., 2018), diagnostic surveys to identify system weaknesses (Halsey and Demas, 2013), and "whole-of-government" governance approaches to address the new cross-sectoral coordination challenges (OECD, 2017), such as those imposed by Covid-19. This extreme diversity in concepts and methods can make systems approaches seem ill-defined and opaque to researchers and policymakers from outside the systems tradition, and has limited engagement with their insights.

What, then, is the common theoretical core of systems approaches to public service delivery? What are the key distinctions among them, and to which kinds of questions or situations are

different types of systems approaches best suited? And what is the relationship between systems approaches and standard impact evaluation-based approaches to using evidence to improve public service delivery?

We address these questions by reviewing and synthesizing the growing literature on systems approaches. We focus our review on three policy sectors in which systems approaches have gained increasing currency in high- as well as middle- and low-income countries alike: health, education, and infrastructure. These approaches have developed largely independently in each sector, which not only creates opportunities for learning across sectors but also allows us to distill a common set of conceptual underpinnings from a diverse array of methods, contexts, and applications.

Our article thus has two linked goals. First, we aim to provide shared conceptual foundations for engagement between researchers within the systems tradition and those who work outside the systems community but share an interest in the role of context and complexity in public service delivery and policy evaluation. Second, we aim to cross-pollinate ideas and facilitate discussion within the systems research community, among researchers and practitioners from different sectoral backgrounds or disciplinary communities.

Based on our review, we argue that systems approaches can best be understood not as a single method, but as a diverse set of analytical responses to the idea that *multi-dimensional complementarities* between a policy and other aspects of the policy's context (e.g. other policies, institutions, social and economic context, cultural norms, etc.) are the first-order problem of policy design and evaluation. Such complementarities are present when the impact of a group of variables on an outcome is greater than the sum of its parts. For example, the

impact of a new pay-for-performance scheme on health service delivery might depend not just on multiple characteristics of the scheme's design but also on the presence of effective data monitoring and auditing systems, on health workers' intrinsic motivation and career incentives, on the availability of resources to pay bonuses, and on whether political economy considerations permit the payment of bonuses – as well as potentially dozens of other dimensions along which contexts might vary. Whereas standard impact evaluation methods typically seek to address these complexities by finding a way to "hold all else constant" in order to causally identify the impact of a policy intervention on an outcome variable, systems approaches focus in on the "all else" in order to better understand the complex ways in which policies' effectiveness might vary across contexts and time or depend on the presence of complementary policy interventions. The systems character of a piece of research can thus pertain to its question, theoretical approach, and/or empirical methodology.

Within the broad umbrella of systems approaches, we distinguish between "macro-systems" approaches and "micro-systems" approaches. The former are primarily concerned with understanding the collective coherence of a set of policy interventions and various other elements of context, whereas the latter focus in on a single policy intervention (like most standard impact evaluations) but focus on understanding its interactions with contextual variables and other policy interventions (rather than necessarily obtaining an average treatment effect). We further review and distinguish among different analytical methods within each of these two categories, and link these different methods to different questions and analytical purposes. In particular, we suggest that the choice of which micro-systems approach to adopt depends on the degree to which contextual complementarities affect a policy's *efficacy* (i.e. the extent to which a given policy has consistent impacts across contexts) and *implementability* (i.e the extent to which a given policy can be delivered or implemented correctly). We combine

these two dimensions to construct four stylized types of linked question types and research approaches: "what works"-style impact evaluation (consistent efficacy, consistent implementability); external validity (inconsistent efficacy, consistent implementability); implementation science (consistent efficacy, inconsistent implementability); and complex systems (inconsistent efficacy, inconsistent implementability). While not necessarily straightforward to apply in practice, this parsimonious framework helps explain why and when researchers might choose to adopt different systems-based methods to understand different policies and different questions – as well as when adopting a systems perspective may be less necessary.

Of course, these questions are also of interest to impact evaluators outside the systems tradition, and many of the methodological tools that systems researchers use are familiar to them. Whereas systems approaches are sometimes perceived as being from a different epistemological tradition than standard impact evaluation methods (e.g. Marchal et al., 2012) we view the underlying epistemology of systems approaches as consistent with that of impact evaluation. The main difference is the extent to which complementarities are relevant and hence how tractable understanding their impact is through standard impact evaluation methods with limited statistical power and counterfactual availability. While issues of heterogeneity, complementarity, and external validity can be addressed using standard impact evaluation methods (e.g. Bandiera et al., 2010; Andrabi et al., 2020), systems approaches presume (implicitly or explicitly) that such interactions are often high-dimensional (i.e. across many different variables) and thus intractable with limited sample sizes.[1] What distinguishes systems approaches, then, is mainly a different *prioritization* of these questions, and consequently a greater openness to methods other than quantitative impact evaluation in answering them. In

[1] See Hausmann (2008), Pritchett (2015), and Williams (2020), among others, for related discussions.

this view, systems approaches and impact evaluation are thus better understood as complements, not mutually inconsistent alternatives, for creating and interpreting evidence about policy effectiveness.

The remainder of our article proceeds as follows. Section 2 briefly discusses our review method. Section 3 presents a range of definitions of systems approaches from the literature, then synthesizes them into what we characterize as their common theoretical core. Section 4 reviews and typologizes macro-systems approaches across health, education, and infrastructure and offers a conceptual framework for synthesis, and Section 5 does the same for micro-systems approaches. Section 6 discusses how researchers and practitioners should go about selecting which type of systems approach (if any) is best suited for their purposes, and Section 7 concludes by discussing the connections between systems approaches to public service delivery and other well-established theoretical and methodological concerns in economics, political science, and public administration.

2. Review Method

Our review of systems approaches in public service delivery focuses primarily on three sectors in which they have increasingly gained popularity: health, education, and infrastructure. However, the purpose of this article is not to provide a comprehensive survey of the systems literature in each of these sectors, as there already exist several excellent sector-level survey papers on systems approaches (e.g. Gilson, 2012; Carey et al., 2015; Hanson, 2015 for health; Pritchett, 2015 for education; Saidi et al., 2018 for infrastructure). Instead, this article's main contribution is to synthesize ideas and insights from these divergent sectoral literatures to make them more accessible to each other and to readers from outside the systems tradition.

We conducted selective literature reviews within each sector aimed at synthesizing the breadth of questions, theories, methods, and empirical applications that comprise the range of methods used in the systems literature across these sectors. In doing so, we drew on a combination of foundational systems texts of which we were already aware, the existing sectoral review papers listed above, input from sectoral experts, and keyword searches in databases. We then used the citations and reference lists of these to iteratively identify additional articles of interest, stopping when we reached a point of saturation.[2] The result is not a systematic review in the formal sense of the term, but nevertheless provides a detailed and consistent picture of the state of the literature in each sector. In that sense, our methodology shares overlaps with a "problematizing" (Alvesson and Sandberg, 2020) or a "prospector" review (Breslin et al., 2023) where our focus is more on defining a new set of domain and boundaries that can allow us to critically reimagine the existing literature, challenge pre-existing conceptions, and build new theory, rather than offering a representative description of the field through a narrow lens. In addition to literature specifically about each of these sectors, we also draw on non-sector-specific work on systems approaches to understanding service delivery in complex and unpredictable systems more generally. We include in our review texts that self-describe as systems-based, as well as many which share similar questions, theoretical approaches, and empirical methods but which do not necessarily adopt the language of systems approaches.

For clarity and brevity, and in line with the article's purpose, we focus the main text on presenting an overall synthesis with illustrative examples rather than on decreasing readability by trying to cover as many studies as possible. We include a more detailed (though still inevitably selective) sector-by-sector summary in an Online Appendix for interested readers.

[2] The Online Appendix gives further details on our literature review methodology.

Our review and synthesis is not necessarily intended as an argument in favor of systems approaches being used more widely, nor as a critique of research outside the systems tradition. Neither should it be read as a critique of systems approaches. While we do believe that both the general thrust of systems approaches and many of the specific ideas presented by them are important and useful, our goal is merely to present a concise survey and a set of clear conceptual distinctions so that readers can determine what might be useful to them from within this diverse array of perspectives and methods and can better converse across disciplinary and sectoral boundaries without the caricaturing and misrepresentation that have often marred these conversations. Doing this inevitably creates a tension between staying faithful to the way in which researchers in these fields view their work, and the necessity of communicating about it in ways that will be intelligible to readers from other fields. We hope that we have struck this balance well and that readers will be understanding of the challenges of doing so on such a broad-ranging topic.

3. Defining Systems Approaches

Systems approaches are defined in different ways across different sectors, but tend to share a common emphasis on the multiplicity of actors, institutions, and processes within systems. For example, the World Health Organization (2007, p. 2) defines a health system as consisting of "all organizations, people and actions whose primary intent is to promote, restore or maintain health." In education, Moore (2015, p. 1) defines education systems as "institutions, actions and processes that affect the 'educational status' of citizens in the short and long run." In infrastructure, Hall et al. (2016, p. 6) define it as "the collection and interconnection of all physical facilities and human systems that are operated in a coordinated way to provide a particular infrastructure service".

Despite their differences, these definitions imply a focus of systems on "holism" (Midgley 2006; Hanson 2015), or the idea that individual policies do not operate in isolation. Whereas a great deal of research and evidence-based policymaking focuses on studying the effectiveness of a single policy in isolation – often by means of using impact evaluation to estimate an average treatment effect – in practice each policy's effectiveness depends on other policies and various features of the contextual environment (Hanson, 2015). As De Savigny and Adam (2009, p.19) write in their seminal discussion of health systems, "every intervention, from the simplest to the most complex, has an effect on the overall system, and the overall system has an effect on every intervention." This emphasis on interconnection has made the study of complexity (e.g. Stacey, 2010; Burns & Worsley, 2015) a natural source of inspiration for those seeking to apply systems approaches to the study of development and public service delivery.

But despite the growing popularity of systems approaches, there remains significant ambiguity around their meaning, with no universally accepted definition or conceptual framework beyond their shared emphasis on holism, context, and complexity (Midgley, 2006). Even those writing within the systems tradition have pointed out that the field has used "diverse" and "divergent" concepts and definitions, leading the field as a whole to be sometimes characterized as "ambiguous" and "amorphous" (Cabrera et al., 2008). This lack of a commonly agreed definition and theoretical basis has made a precise and concise response to the question "what is a systems approach to public service delivery, and how is it different to what already exists?" difficult to obtain.

We argue that instead of viewing a systems approach as a specific method, system approaches are better understood as a diverse set of analytical responses to the idea that the first-order

challenge of policy design and evaluation is to understand the multi-dimensional complementarities between a policy and other aspects of the policy's context (e.g. other policies, institutions, social and economic context, cultural norms, etc.). By complementarities, we refer to the formal definition under which two variables – e.g. a variable capturing the presence of a particular policy and another variable capturing some aspect of the policy's context – are considered complements when their joint effect on an outcome variable is greater than the sum of their individual effects on that variable.[3] By multi-dimensional, we refer to the idea that these complementarities might not just be among two or three variables at a time (as impact evaluations often seek to estimate) but among so many variables that estimating them in a standard econometric framework often becomes intractable. While this definition is limited in its precision by the need to adequately encompass the enormous diversity of systems approaches we discuss in subsequent sections, it captures the theoretical core – the emphasis on understanding multi-dimensional complementarities – that ties them all together.

Advocates of systems approaches often contrast this emphasis with the naïve use of impact evaluation to obtain an average treatment effect of a policy which is then used to guide adoption decisions across a wide range of contexts and populations. Of course, the rapid growth in attention towards and research on issues of external validity and implementation within economics and political science (Deaton, 2010; Pritchett & Sandefur, 2015; Bold et al., 2018) makes this something of a "straw-man" characterization in many cases. In practice, both "impact evaluators" and "systems researchers" care about average treatment effects as well as about heterogeneity, mechanisms, and interactions. Indeed, it is noteworthy that the groups of researchers and practitioners with whom systems approaches have gained the most currency in

[3] The prevalence of complementarities in bureaucracies has also been emphasized in organizational research (e.g. Ichniowski and Shaw 2003; Brynjolfsson and Milgrom 2013) and used in explaining institutional path dependence (Deeg, 2007).

the past two decades are (at least in the health and education sectors) those who most often find themselves working with, arguing against, or attempting to expand the boundaries of impact evaluators. But while easily over-exaggerated, the distinction does capture the different frame of mind with which systems researchers approach evidence-based policy, in which understanding complementarities among policies and their context is the *primary* focus of analysis, prioritized (in many cases) even over estimating the direct effect of a policy itself. Whereas a standard impact evaluation seeks primarily to understand the impact of a specific policy holding all else constant, a systems approach to the same policy seeks primarily to understand how the "all else" affects the policy's impacts.

Among studies that self-identify as focusing on systems, one can draw a conceptual distinction between studies that are system-focused *in substance* (due to their scale or topic) and those that are system-focused *in approach* (due to their methodological or theoretical emphasis on issues of context, complementarity, and contingency). This article focuses mainly on the latter category. Although in practice these categories overlap significantly and the distinction is a blurry one, it nonetheless helps avoid the excessive conceptual spread that could result from referring to every study on "the health system" (or the education or infrastructure systems) as a "systems approach".

Before we proceed to drawing distinctions among different types of systems approaches, it is worth noting two additional characterizations of systems approaches that are often made by systems researchers. First, systems approaches are sometimes viewed as being more question- or problem-driven than standard research approaches, with a focus on real world issues and linkages to actual government policy choices (e.g. Mills, 2012; Gilson, 2012; Hanson, 2015). While this characterization risks giving short shrift to the policy relevance of a great deal of

research outside the systems tradition, there is also a natural linkage between embeddedness in an actual policy decision and a concern for understanding how a wide range of factors interlock, since policymakers must often deal with a breadth of challenges that researchers might choose to abstract away in the pursuit of parsimony. Second, some systems researchers emphasize that service delivery is not only complicated (in the sense of involving many moving parts) but also complex (in the sense of possessing dynamics that are non-linear and/or fundamentally unpredictable) (Sheikh et al., 2011, Snyder, 2013). We do not include this aspect of complexity in our core definition presented above, since it is far from universally shared among systems approaches, but return to discuss this issue further in section 6 below.

4. Macro-systems Approaches

One branch of systems approaches responds to the challenge posed by the presence of multi-dimensional complementarities across policies and contextual factors by taking a step back to try to examine questions of policy effectiveness from the standpoint of the entire system. These *macro-systems approaches* are focused not on the impact of a specific policy in isolation, but on understanding how the entire system functions to deliver desired outcomes. Macro-systems approaches thus focus on understanding coherence and interconnectedness between different policies, structures, and processes. In doing so, they also tend to define boundaries of the system in question, although this is often a challenging task (Carey et al., 2015).

Our review of macro-systems approaches across the health, education, and infrastructure sectors highlights that these approaches lie on a spectrum of the specificity with which they define causal relationships between different system components. This includes approaches ranging from those that merely outline lists or typologies of various system components to

those that tend to specify causal relationships between system components through specific numerical parameters. Along this spectrum it is possible to distinguish three types of macro-systems approaches:

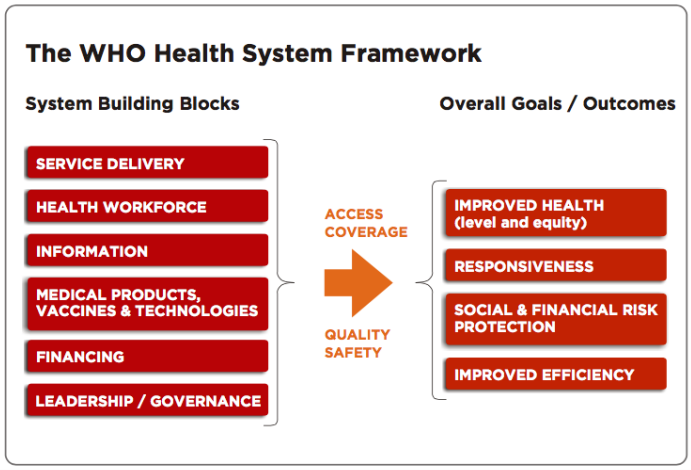
- *Inventory approaches*, which are primarily descriptive and use typologies or lists to define a comprehensive universe of system components such as the types of stakeholders, functions, institutions, or processes within a system;
- *Relational approaches,* which go a step further to posit broad causal relationships or complementarities between system features, based mainly on theory[4]; and
- *Systems modelling,* which conceptualizes the system through precise mathematical causal relationships between different system components.

Inventory approaches list different components and /or typologies within a system with the aim of cataloguing the whole range of factors that determine the outcomes or performance of a given system (usually defined sectorally). An example of such an approach is the seminal WHO health systems framework which characterizes the health system as comprising six key functional building blocks – service delivery, health workforce, information, medical products (including both vaccines and technologies), financing, and leadership and governance – and links them to the broader health system goals (World Health Organization, 2007). As Figure 1 shows, the strength of such inventory frameworks is their very wide scope in terms of identifying the full range of potential determinants and outcomes of a system, but this breadth is achieved by limiting the specificity of the causal relationships they posit. Similarly, the World Bank Systems Approach for Better Education Results (SABER) defines the education

[4] The "inventory" and "relational" terms are drawn from Hanson's (2015) excellent review of the health systems literature.

system in terms of thirteen different functions (e.g. education management information systems, school autonomy and accountability, student assessment) with a link to improved student learning without specifying the relationship between these functions (Halsey and Demas, 2013).

Figure 1: WHO Health System Framework

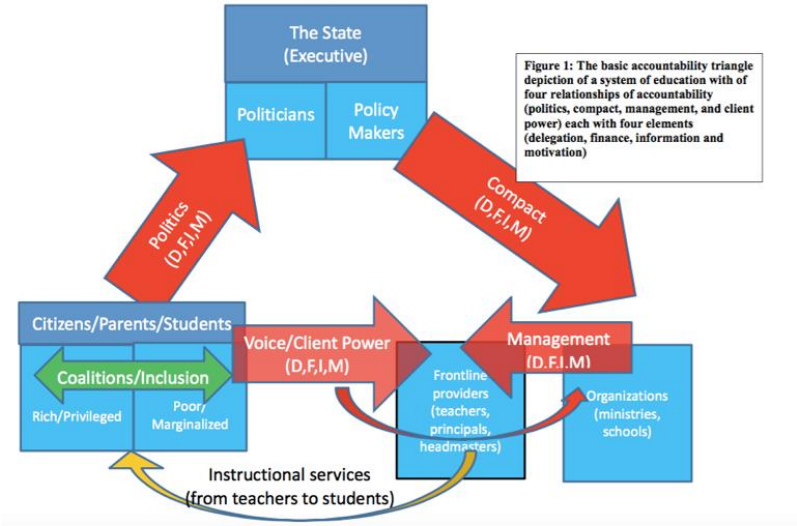


Source: De Savigny and Adam (2009)

Like inventory approaches, relational macro-systems approaches list different system components, but go a step further in specifying the nature or direction of specific relationships or complementarities between them. For example, Gilson (2003) conceptualizes the health system as a set of trust relationships between patients, providers, and the wider institutions. This differs from an inventory approach in more narrowly specifying both the content and direction of relationships among actors, which makes it more analytical but also limits its scope. It also demonstrates how such frameworks may also consider the software (i.e. institutional environment, values, culture and norms) in addition to the hardware (i.e. population, providers, organizations) of a health system (Sheikh et al., 2011). In the education sector, Pritchett (2015) adopts a relational approach to characterizing the education system

through accountability links between different actors such as the executive apparatus of the state, organizational providers of schooling (such as ministries and schools), frontline providers (such as head teachers and teachers), and citizens (such as parents and students).[5] He argues that the system of education works when there is an adequate flow of accountability across the key actors in the system across four design elements: delegation, financing, information and motivation (see Figure 2). Similarly, in the infrastructure sector, Ottens et al. (2006) propose a high-level framework to characterize how technical elements in an infrastructure system may interact with human actors and social institutions to determine system performance. But while such relational approaches are more specific than inventory approaches in their definition of elements and causal relationships, they are still broad enough that their use is more as a conceptual framework for arraying factors and nesting hypotheses than as an operationalizable model of the system.

Figure 2: Education System Framework



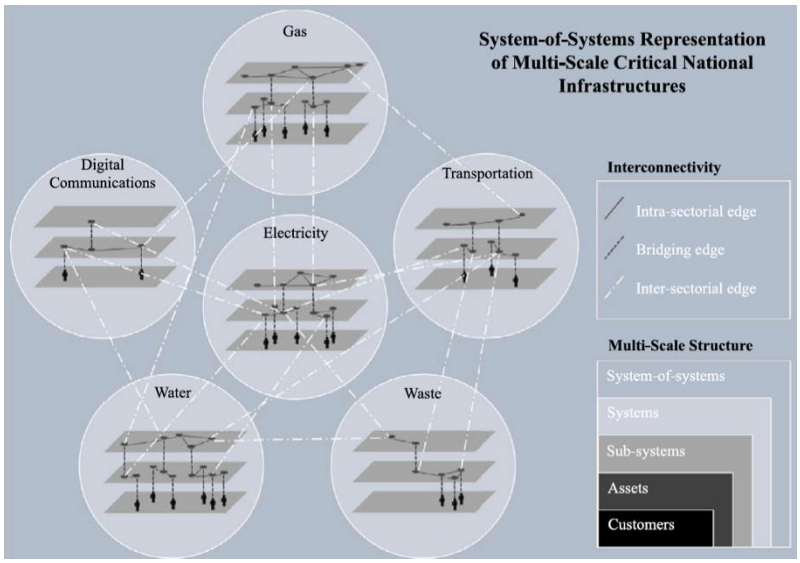
Source: Pritchett (2015)

[5] Pritchett's (2015) framework builds upon the World Bank's (2004) well-known "accountability triangle", itself a relational framework.

Systems modelling approaches take this next step of precisely specifying variables, causal relationships among these system components, and numerical parameters on these relationships. Such models typically combine theory with statistical methods, and draw on a range of quantitative techniques such as systems dynamics, structural equation modelling, and structural econometric modelling (e.g. Reiss & Wolak, 2007; Homer & Hirsch, 2006).[6] Thacker et al. (2017), for example, develop a network-based *systems-of-systems* model for critical national infrastructures, where each type of infrastructure such as water or electricity is a sub-system comprising of a group of nodes and edges with their specific flows (see Figure 3). They use this model to perform a multi-scale disruption analysis and draw predictions on how failures in any individual sub-systems can potentially lead to large disruptions. In the health sector, Homer and Hirsch (2006) develop a causal diagram of how chronic disease prevention works and then use systems dynamic methodology to develop a computer-based model to test alternate policy scenarios that may affect the chronic disease population. In the education sector, Kaffenberger and Pritchett (2021) combine a structural model with parameter values from existing empirical literature to predict how learning outcomes would be affected under different policy scenarios such as expanding schooling to universal basic education, slowing the pace of curriculum, and increasing instructional quality.

[6] Systems dynamics methodology involves computer simulation models to capture processes of accumulation and feedback using numerical values (Homer & Hirsch, 2006). This is related methodologically to the type of formal theoretical and empirical structural modelling methods often used in the social sciences; the distinction between them lies less in the methods themselves than in the intent to model relationships across an entire system or sub-system.

Figure 3: Infrastructure System representation with six critical national infrastructures



Source: Thacker et al. (2017)

The three macro-systems approaches outlined above can have different types of uses and benefits depending on the question of interest. For example, systems researchers often use frameworks developed through inventory approaches to develop diagnostic tools to understand strengths and weaknesses of systems, such as the World Bank's use of its SABER framework which has been implemented in more than 100 countries to identify potential constraints to system effectiveness (World Bank, 2014). Relational frameworks in turn can be used to array key relationships between system actors, which may be useful for generating important insights for policy design or generating more precise hypotheses for empirical research. Finally, systems modelling approaches are one way of making complex systems analytically tractable by narrowing down on a set of key causal relationships within a system to generate useful predictions and insights about a system (Berlow, 2010). Although systems modelling has been used in the health and education sectors to generate useful predictions, such models have been used more extensively in infrastructure systems research, possibly because the variables are

more quantitative in nature and relatively easier to model in comparison to more human or intangible contextual features in health or education. While conceptually distinct, in practice these three types of macro-systems approaches can overlap, and not every framework is easily classifiable within a single category.

Table 1: Summary of Macro-systems Approaches with Selected Examples

	Inventory Approaches	**Relational Approaches**	**Systems Modelling**
	Descriptive frameworks that present typologies or lists to define different system components	*Frameworks that specify causal relationships or complementarities between those system components.*	*Frameworks that conceptualize the system through very specific numerical causal relationships.*
Health	· WHO (2007): Characterizes the health system as comprising of 6 functional building blocks (e.g. service delivery, health workforce to name a few)	· Gilson (2003): Characterizes the health system in terms of its stakeholders and trust relationships between them.	· Rwashana et al. (2009): Use dynamic synthesis methodology (DSM) to model the immunization system.
Education	· SABER (2011): Characterizes the education system in terms of thirteen different functions.	· Pritchett (2015): Characterizes the education system in terms of its stakeholders and accountability links between them.	· Kaffenberger and Pritchett (2021): Develop a structural model to capture the dynamics of learning in the education system
Infrastructure	· Rinaldi et al. (2001) outline infrastrucure systems in terms of four main dependencies: physical, cyber, geographical/spatial or logical.	· Saidi et al. (2018): Characterize a multi-layered civil infrastructure system with different interdependencies between physical infrastructure sectors and the broader social economic or political environments.	· Thacker et al. (2017): Develop a network-based *systems-of systems* model for national infrastructure comprising of a group of nodes and edges between system components.

Source: Authors' synthesis

5. Micro-systems approaches

While macro-systems approaches offer big-picture frameworks to understand coherence between many system components and policies, micro-systems approaches focus on the effectiveness of a specific policy – just like impact evaluations. However, the central presumption of micro-systems approaches is that policies cannot be viewed in isolation, but rather need to be designed, implemented, evaluated, and scaled taking the wider context and complementarities within the system into account (Travis et al., 2004; De Savingy & Adam 2009; Snyder, 2013; Pritchett, 2015), and so questions and methods mainly revolve around these issues rather than average treatment effects.

Across the health, education, and infrastructure sectors, a diverse range of analytical approaches fit our description of systems approaches. Each of these approaches are likely to be familiar to readers in some disciplines and unfamiliar to others. They include approaches that aim to help evaluators better understand the roles of mechanisms and contextual factors in producing policy impact, such as realist evaluation (Pawson & Tilley, 1997) and theory-driven evaluation (Coryn et al., 2011), as well as a range of qualitative or ethnographic (e.g. George, 2009; Bano & Oberoi, 2020) and mixed method approaches (e.g. Mackenzie et al., 2009; Tuominen et al., 2014) more broadly. They also encompass fields such as implementation science (Rubenstein & Pugh, 2006), some types of meta-analysis and systematic review (e.g. Greenhalgh et al., 2016; Leviton et al., 2017; Masset, 2019), and adaptive approaches to policy design and evaluation (e.g. Andrews et al., 2017). These micro-systems approaches can focus on a variety of levels of analysis, from individuals to organizations to policy networks, but are united by their analytical focus on a single policy at a time rather than on the entire system (as in macro-systems approaches). We briefly summarize each of these methods or approaches in

this section, before the next section develops a framework to link them back to standard impact evaluation and help prospective systems researchers select among them.

Micro-systems approaches' emphasis on heterogeneity is perhaps best captured by the mantra of the "realist" approach to evaluation, which argues that the purpose of an evaluation should be to identify "what works in which circumstances and for whom?", rather than merely answering the question of "does it work"? (Pawson & Tilley, 1997). More specifically, instead of looking at simple cause and effect relationships, realist research typically aims to develop middle-range theories through developing "context-mechanism-outcome configurations" in which the role of policy context is integral to developing an understanding of how the policy works (Pawson & Tilley, 1997; Greenhalgh et al., 2016). For example, Kwamie et al. (2014) use a realist evaluation to evaluate the impact of the Leadership Development Programme (LDP) delivered to district hospitals in Ghana. Focusing on a district hospital in Accra, they used a range of qualitative data sources to develop causal loop diagrams to explain interactions between contexts, mechanisms, and outcomes. They found that while the training produced some positive short-term outcomes, it was not institutionalised and embedded within the district processes. They argue that this was primarily due to the structure of hierarchical authority in the department, due to which the training was seen as a project coming from the top, and thus reduced initiative on the part of the district managers to institutionalize it.

A related approach is theory-driven evaluation, in which the focus is not just on whether an intervention works but also on its mediating mechanisms – the "why" of impact (Coryn et al., 2011). Theory-driven evaluations take as their starting point the underlying theory of how the policy is intended to achieve its desired outcomes (often expressed in the form of a theory of change diagram), and seek to evaluate each step of this causal process. As with realist

approaches, the role of context is critical for theory-driven evaluations, as it is these mechanism-context complementarities that drive heterogeneity of impact across contexts and target populations, and hence the external validity and real-world effectiveness of policies or interventions. Theory-based and realist evaluations both tend to rely on qualitative methods, either alone or as a supplement to a quantitative impact evaluation (i.e. mixed methods), as limitations of sample size, counterfactual availability, and measurement often make it infeasible to document multiple potential mechanisms quantitatively at the desired levels of nuance and rigor.[7]

Another form of qualitative method widely used by systems researchers is ethnography and participant observation. These are used mainly for the diagnosis of policy problems, refining research hypotheses, or designing new policy interventions, rather than evaluating policy impact *ex post*. For example, George (2009) conducts an ethnographic analysis to examine how formal rules and hierarchies affect informal norms, processes, and power relations in the Indian health system in Koppal state. The study shows that the two key functions of accountability in Koppal's health system – supervision and disciplinary action – are rarely implemented uniformly as these are negotiated by frontline staff in various ways depending on their informal relationships. In the education sector, Bano and Oberoi (2020) use ethnographic methods to understand how innovations are adopted in the context of an Indian NGO that introduced a Teaching at the Right Level (TaRL) intervention, and tease out lessons for how innovations can be scaled and adopted in state systems. In this sense, ethnographic research is a more structured and rigorous version of the informal discussions or anecdotal data that policymakers

[7] Magrath et al. (2019) cite various examples of mixed methods research studies under the Raising Learning Outcomes in Education Systems (RLO) research program.

and evaluators often draw upon in making policy or evaluation decisions, and can be integrated into these processes accordingly (alone or alongside some form of impact evaluation).

Systems research often has a specific focus on the implementation, uptake, and scale-up of policy (Hanson, 2015). The discipline of *implementation science* in the health sector, for example, is specifically targeted towards understanding such issues (Rubenstein & Pugh, 2006). Research in implementation science is usually less concerned with the question of what is effective (where there is strong prior evidence on an intervention's efficacy in ideal conditions) and is more concerned with how to implement effectively. Systems researchers who study implementation cater to a set of concerns such as methods for introducing and scaling up new practices, behavior change among practitioners, and the use and effects of patient and implementer participation in improving compliance. Greenhalgh et al. (2017), for example, combine qualitative interviews, ethnographic research, and systematic review to study the implementation of technological innovations in health. They develop the non-adoption, abandonment, scale-up, spread, and sustainability (NASSS) framework to both theorize and evaluate the implementation of health care technologies. Like realist and theory-based evaluation, implementation science research often relies heavily (though not exclusively) on qualitative methods, although these can also be combined with experimental or observational quantitative data.

While these micro-systems approaches are by definition used to analyse the effectiveness of a single policy, some systems researchers have also adapted evidence aggregation methods like systematic reviews and meta-analysis to the interests of systems researchers. While these methods are typically used to summarize impacts or identify an average treatment effect of an intervention by summarizing studies across several contexts, systems researchers focus on

using these methods to identify important intervening mechanisms across contexts. For example, Leviton (2017) argues that systematic reviews and meta-analyses can offer bodies of knowledge that support better understanding of external validity by identifying features of program theory that are consistent across contexts. To identify these systematically, she identifies several techniques to be used in combination with meta-analyses such as a more thorough description of interventions and their contexts, nuanced theories behind the interventions, and consultation with practitioners. While many of these applications rely on integrating qualitative information into the evidence aggregation process, other researchers use these methods in their traditional quantitative formats but focus specifically on systems-relevant questions of mechanisms, contextual interactions, and heterogeneity. For example, Masset (2019) calculates prediction intervals for various meta-analyses of education interventions and finds that interventions' outcomes are highly heterogeneous and unpredictable across contexts, even for simple interventions like merit-based scholarships. Used in this way, there is methodological overlap between meta-analysis in the systems tradition and how it is commonly used in mainstream impact evaluation. This illustrates one of many ways in which the boundaries between "systems" and "non-systems" research is porous, which both increases the possibilities for productive interchange among research approaches but also creates terminological and conceptual confusion that inhibits it.

Stakeholder mapping or analysis is another method used by systems researchers, to either understand issues of policy implementation or policy design. For example, Sheikh and Porter (2010) conduct a stakeholder analysis to identify key gaps in policy implementation. Using data from in-depth interviews with various stakeholders across five states in India, they highlight bottlenecks in HIV policy implementation (from nine hospitals selected by principles of maximum variation). Like ethnography, stakeholder mapping is an example of a micro-

systems approach (because it focuses on the effectiveness of a single policy) but which asks different questions about that policy's effectiveness than standard impact evaluations do.

A final set of micro-systems approaches are grounded in the reality that many questions of policy design and evaluation are situated in complex settings, where policy-context complementarities are so numerous and specific to the contextual setting that the effectiveness of a policy is impossible to predict, for all intents and purposes. Systems researchers argue that for such *complex systems*, which have many "unknown unknowns" with few clear cause and effect relationships, various negative and positive feedback loops and emergent behaviours (Bertalanffy, 1971; Snowden & Boone, 2007), there is a need for a different set of analytical approaches to policy design and evaluation (e.g. Snyder, 2013). This perspective eschews not only the idea of 'best practice' policies but also sometimes the idea of basing adoption decisions on policies' effectiveness in other contexts, because policy dynamics are viewed as so highly context-specific.

A core idea in complex systems theory is that the processes of policy design and implementation should involve an on-going process of iteration with feedback from key stakeholders and decision-makers in the system. For example, Andrews et al. (2013) argue that designing and implementing effective policies for governments in complex settings requires locally driven problem-solving and experimentation, and propose an approach called problem-driven iterative adaptation (PDIA) that emphasizes local problem definition, design, and experimentation. In a different vein, Tsofa et al.'s (2017) "learning sites" approach envisions a long-term research collaboration with a district hospital in which researchers and health practitioners work together over time to uncover and address thorny governance challenges. While the learning site serves to host a series of narrower research studies, the most important

elements include formal reflective sessions being regularly held among researchers, between researchers and practitioners, and across learning sites to study complex pathways to change. Such approaches are also closely linked to the *living lab* methodology, which relies on innovation, experimentation, and participation for diagnosing problems and designing solutions for more effective governance (Dekker et al., 2019).[8]

The types of micro-systems approaches discussed above and presented in Table 2 are neither mutually exclusive nor collectively exhaustive of all possible micro-systems approaches, but illustrate the breadth and diversity of such approaches. Table 2 also illustrates the variation across sectors in the range of approaches that are commonly used. The health sector has the broadest coverage across different types of methods. The education sector also shows fairly broad coverage across methods, while also demonstrating growing attention towards systems approaches in response to greater concerns of external validity following the surge of education-related impact evaluations (especially in international development) over the last decade. The use of micro-systems approaches in infrastructure is comparatively limited. This is possibly because infrastructures have high up-front costs that demand more *ex ante* cost-benefit analysis and planning (often through macro-systems approaches) rather than *ex post* evaluations of the impacts of specific infrastructures through micro-systems approaches.

Table 2: Summary of Micro-systems Approaches

	Realist and Theory-driven evaluations	Ethnographic field studies	Implementation Science	Meta-analysis and systematic reviews	Stakeholder analysis	Approaches for Complex Systems
Health	· Kwamie et al. (2014): A realist evaluation to study the impact of a leadership and management initiative in public health sector in Accra, Ghana.	· George (2009): Ethnographic field studies to study accountability relationships in health systems in India.	· Greenhalgh et al. (2017): Ethnographic research with a systematic review to develop a framework for understanding implementation of health-based technological innovations.	· Kristjansson et al. (2015): Meta-analysis of food supplementation programs on child health showing how place of delivery matters for impact.	· Sheikh and Porter (2009): In-depth stakeholder interviews to understand key gaps in HIV implementation.	· Tsofa et al. (2017): 'Learning sites' approach in which researchers and practitioners work together in a specific geographical space to study decentralization in Kenya.
Education	· Magrath et al. (2019): Quantitative longitudinal data on student outcomes with qualitative interviews to diagnose how accountability functions.	· Bano and Oberoi (2020): Ethnographic study to understand adoption of innovations in an NGO (Pratham) and its lessons for state systems.		· Masset (2019): Meta-analysis of education interventions using prediction intervals (to account for heterogeneity across interventions).		· Crouch and De Stefano (2017): 'Doing Development Differently (DDD)' initiative which emphasizes solutions to be locally designed, owned, implemented, and iterated through repeated cycles.
Infrastructure				· Filazzola et al. (2019): Meta - analysis to study whether green infrastructure is beneficial for biodiversity,	· Tuominen et al. (2014): A method called pluralistic backcasting, in which multiple visions of the future are developed through a participatory and interdisciplinary process.	

Source: Authors' synthesis

6. Systems Approaches and Impact Evaluation

The review of systems approaches in the preceding two sections illustrates the sheer diversity of topics, questions, theories, and methods that can fall within the broad label of systems approaches. It also shows that while systems approaches are sometimes rhetorically positioned in opposition to standard impact evaluation approaches, many of the concerns motivating systems researchers (such as attention to mechanisms, heterogeneity, external validity, implementation and scale-up, the use of qualitative data) can and increasingly are being addressed within the impact evaluation community. At the same time, it is also generally true that systems approaches differ substantially in their prioritization of questions and hence the types of evidence in which they are most interested, so these differences are not purely semantic.

How, then, should a researcher or policymaker think about whether they need to adopt a systems approach to creating and interpreting evidence? And if so, which type of systems approach might be most relevant? In this section, we offer a brief conceptual synthesis and stylized framework to guide thinking on these questions.

For macro-systems approaches, the relationship to standard impact evaluation methods is fairly clear. Macro-systems approaches array the broad range of policies and outcomes relevant to understanding the performance of a given sector, and impact evaluations examine the effect of specific policies on specific outcomes within this framework. Macro-systems frameworks can thus add value to impact evaluation-led approaches to studying policy effectiveness by providing a framework with which to cumulate knowledge, suggesting important variables for impact evaluations to focus on (and potential complementarities among them), and highlighting

gaps in an evidence base. Being more explicit in couching impact evaluations in some kind of broader macro-system framework – whether inventory, relational, or systems modelling – could thus enhance the evidentiary value of systems approaches, as indeed it has begun to do in the systems literatures in the health, education, and infrastructure sectors (e.g. Spivack 2021).

For micro-systems approaches, however, the relationship to (and distinction from) standard impact evaluation methods is more blurry. Among other reasons, this is because our definition of systems approaches as being concerned with multi-dimensional complementarities does not give much guidance as to which types of systems questions and methods might be related to different types of potential complementarities.

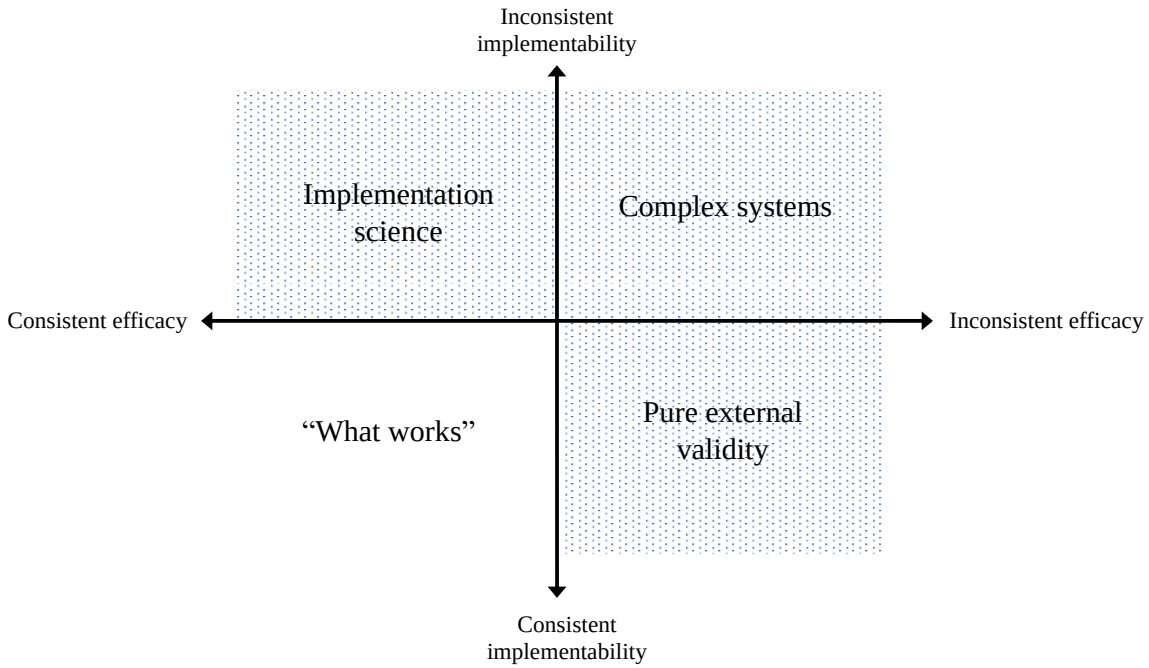
We therefore propose a simple framework that uses a policy's *consistency of implementability* and *consistency of efficacy* to guide choices about the appropriateness of different evidence-creation approaches.[9] By consistency of implementability, we mean the extent to which a given policy can be delivered or implemented correctly (i.e. the desired service delivery outputs can be produced) across a wide range of contexts. Policies whose effective implementation depends on important and numerous complementarities with other policies or aspects of context will tend to have lower consistency of implementability, since these complementary factors will be present in some contexts but not others, whereas policies for whom these complementarities are relatively fewer or less demanding will be able to be implemented more consistently across a wide range of contexts. By consistency of efficacy, we mean the extent to which delivery of a given set of policy outputs results in the same set of outcomes in society across a wide range

[9] Other authors have made similar distinctions among policies with respect to questions of implementation, external validity, and scale-up (e.g. Pritchett and Woolcock, 2004; Bates and Glennerster, 2017; Pritchett, 2017) or with respect to the complexity of problems (Snowden and Boone, 2007). We build on these distinctions and deploy them for a different purpose.

of contexts. As with implementability, policies whose mechanisms rely on many important complementarities with other policies or aspects of context will tend to have lower consistency of efficacy across contexts, and vice versa.

Putting these two dimensions together (Figure 4) yields a set of distinctions among four different stylized types of evidence problems, each of which can be addressed most effectively using different methods for creating and interpreting evidence. In interpreting this diagram, several important caveats are in order. First, this framework is intended to help readers organize the extraordinarily diverse range of micro-systems approaches identified in our review and summarized in our preceding sections, and to identify when they might want to adopt a systems approach and which type might be most useful. But it is not comprehensive taxonomy of all micro-systems approaches, nor do all methods reviewed fit neatly into one category. Second, while we present four stylized "types" of evidence problems for simplicity, the underlying dimensions are continuous spectrums. Finally, complementarities exist and context matters for all policies to at least some extent; the distinctions presented here are intended to be relative in nature, not absolute. With these caveats in mind, we discuss each of these types in turn, highlighting their relationship both to different micro-systems methods as well as to standard impact evaluation approaches.

Figure 4: Synthesizing Micro-systems Approaches



Source: Author's synthesis

The top-left quadrant of Figure 4 corresponds to types of policies which are consistently efficacious across contexts, but which are challenging to implement effectively. We refer to these problems as "implementation science" problems. Handwashing in hospitals is an example of a type of policy that falls in this quadrant, as it is simple and universally effective in reducing hospital-acquired infections but also extremely difficult to get health workers to do routinely. Increasing rates of childhood immunization is another example, as well-established vaccinations are consistently efficacious but many children fail to receive immunizations every year. If a policymaker were considering adopting a policy of promoting vaccinations of children, she ought to be less interested in reading existing evidence (or creating new evidence through research) on the efficacy of the vaccines themselves than in evidence about how to increase vaccination rates.

As discussed in the previous section, implementation science researchers have used a range of methods – qualitative, quantitative, mixed – and theoretical perspectives (e.g. realist evaluation) to address implementation-type problems. Outside of the systems tradition, this concern with the nitty-gritty details of how to better deliver policies and the consequences of minor variations in implementation for take-up is perhaps most closely paralleled by Duflo's (2017) vision of economists (and presumably evidence-creators in other disciplines) as "plumbers" helping governments to improve delivery by varying and evaluating program details. So while implementation is clearly a core focus of many types of systems approaches, this is not to say that researchers who do not self-identify as systems researchers are uninterested in it. That said, systems researchers perhaps tend to be more willing to focus their attention exclusively on implementation issues, as distinct from the policy's impact on final outcomes – a choice which is justifiable for the type of evidence problems posed by policies that share the features of consistent efficacy but inconsistent implementability.

This contrasts to the scenario in the bottom-right quadrant, where a policy is simple to implement but has highly variable efficacy across contexts. This is the classic external validity question: will a policy or intervention that works in one context work in a different context?[10] An example of such a problem is merit-based scholarships for education, which are relatively easy to implement in most contexts, but can have high variance in effectiveness across contexts (Masset, 2019). In terms of methodological responses to such problems, realist and theory-driven evaluations are commonly used by systems researchers to understand these issues of heterogeneous effects and fit with context. Meta-analysis and systematic reviews are also

[10] We call this quadrant "pure" external validity because in practice many impact evaluations (and hence discussions of external validity) combine efficacy and implementation when measuring policy impact or effectiveness, whereas we distinguish between external validity as a matter of a policy's efficacy across contexts (which abstracts from implementation quality) rather than its effectiveness across contexts (which includes implementation quality).

commonly used within the systems tradition to aggregate evidence across studies, but typically with a focus on identifying how context influences policy efficacy more than on estimating an overall average treatment effect, often by supplementing quantitative impact estimates with qualitative data and attention to mechanisms and context (e.g. Greenhalgh et al., 2016; Leviton, 2017). Of course, impact evaluation researchers outside the systems tradition are also increasingly recognizing these issues as important, so once again the difference is largely one of prioritization of questions and of methodological pluralism in addressing them.

Policies which are both inconsistently implementable and inconsistently efficacious fall into the category of *complex systems*. These exhibit features that arise from important and numerous complementarities with other policies and with features of the context, such as: emergent behaviours that are not explained by those interactions in isolation; non-linearities; and system self-organization whilst operating across multiple levels and time periods (Sabelli, 2006). Examples of complex system-type problems in public service delivery include many organization- and sector-level reform efforts, which by their nature affect numerous actors (some of whom are organized and strategic), and depend on the existing state of the system and presence of other related policy interventions. Evidence creation and use takes on very different forms for these type of problems, since knowing that a particular policy worked in another context is unlikely to be informative about its effect in a new context.[11] Evidence generation and learning therefore has to take on very local forms, such as the adaptive experimentation methods (e.g. Andrews et al., 2017) and learning sites and living labs (e.g. Sabel et al., 2012; Tsofa et al., 2017; Dekker et al., 2019) discussed in section 5 above.

[11] The subset of systems studies that view complexity as generating fundamental uncertainty and unpredictability in outcomes (e.g. Sheikh et al., 2011; Snyder, 2013) could be viewed as an extreme case within this quadrant. The underlying epistemological question of whether the outcomes of such systems are impossible to predict or just very difficult to predict is beyond the scope of this article.

Finally, some policies may fall in the bottom-left quadrant of Figure 4 (consistent implementability, consistent efficacy). Such policies are actually relatively amenable to straightforward evaluate-and-transport or evaluate-and-scale-up forms of evidence-based policy, so delving deeply into the complexities of context and broader systems may be unnecessary – or at least not a priority for scarce attention and resources. While context matters for the implementability and efficacy of all policies to some degree, policies such as cash transfers have been shown to be consistently effective in achieving poverty reduction outcomes across a wide range of contexts and are relatively simple to implement. As Bates and Glennerster (2017) note, it is a fallacy to think that all interventions must be re-evaluated in every context in which they are tried, and for policies in this bottom-left quadrant systems approaches might not be necessary at all. Just as there are complex system-type policy problems for which evidence is not generalizable and nearly all learning must be local, there are also "what works"-type policy problems for which evidence is highly generalizable. The challenge for selecting a method of evidence generation and interpretation, then, is being able to predict *ex ante* which type of policy problem one is facing.

How might a researcher or policymaker actually go about deciding which quadrant of this framework they are in when deciding what type of evidence they need in order to make decisions about the adoption and design of a new policy? Several approaches are possible, although each face their own challenges. First, one might approach the question of consistency of implementability and efficacy empirically, by aggregating evidence across multiple contexts and/or target groups through systematic review and meta-analysis. Indeed, multi-intervention meta-analyses such as Vivalt (2020) demonstrate that some interventions exhibit much higher heterogeneity of impact across contexts. Unfortunately, such meta-analyses do not routinely distinguish between implementation and efficacy as causes for this heterogeneity, although in

principle they could – particularly when quantitative methods are supplemented with qualitative data in trying to aggregate evidence about interventions' full causal chains (e.g. Kneale et al., 2018). Second, one could approach the question theoretically, by developing priors about the complexity of each policy's theory of change (i.e. intended mechanism) and its scope for complementarities with other policies or aspects of context in terms of implementation and efficacy. Finally, Williams (2020) proposes a methodology of *mechanism mapping* that combines theory-based and empirics-based approaches to developing predictions about how a policy's mechanism is likely to interact with its context, and thus how heterogeneous its implementability and efficacy are likely to be. All of these approaches have obvious limitations – limited evidence availability, and the difficulty of foreseeing all potential complementarities and their consequences – and in practice would likely need to be combined. Figure 4 is thus likely to be of more use as a conceptual framework or heuristic device than as a device for formally classifying different types of policies. But it may nonetheless help researchers and practitioners structure their thinking about why different types of policies might present different needs in terms of evidence generation.

7. Conclusion

This article has synthesized a wide range of literature that falls under the broad label of systems approaches to public service delivery, drawing key distinctions within it and linking it to standard impact evaluation-led approaches to evidence-based policymaking. Based on our review of studies in health, education, and infrastructure, we have argued that systems approaches are united in their focus on multi-dimensional complementarities between policies and aspects of context as the key challenge for creating and using evidence. This results in a different prioritization of types of questions and greater methodological pluralism, and also

gives rise to a range of different types of systems approaches, each suited to different situations and questions.

Our systems-perspective synthesis in some ways echoes, but goes beyond, discipline-specific attempts to grapple with these issues. It also illustrates ways in which the relevance of systems approaches extends beyond being a set of considerations about how best to undertake policy evaluations. In economics, for instance, issues of complementarity among management structures and processes are perhaps the central focus of the field of organizational economics (Brynjolfsson & Milgrom, 2013) as well as common focuses (at least along one or two dimensions) of impact evaluations (Bandiera et al., 2010; Andrabi et al., 2020). Indeed, Besley et al.'s recent (2022) review of the literature on bureaucracy and development (which also calls for a systems perspective) highlights the potential for this literature to draw increasingly on organizational economics and industrial organization. Similarly, understanding the impact of policies in general rather than partial equilibrium has long been valued (Acemoglu, 2010) and issues of external validity, implementation, and policy scale-up are now at the forefront of impact evaluation (e.g. Duflo 2017; Vivalt, 2020). In comparative politics, discussion of scope conditions for theories and mixed methods are frequently used to understand mechanisms and heterogeneity (e.g. Falleti et al., 2009). And in public administration, questions around how to incorporate complexity of policy implementation and governance networks in research methods (Klijn, 2008), and new governance approaches to address policy design in the face of such complexity are being increasingly discussed (OECD, 2017).

Among practitioners, there is growing recognition that policies are designed and implemented in systems where different layers of administration, personnel, and institutions are intertwined. This has resulted in the production of various guides and frameworks on how policymakers

can use tools from systems approaches to design and implement policy. For example, Woodhill and Millican (2023) offer a framework for how the UK Foreign, Commonwealth, and Development Office and its partners can employ systems thinking in their working practices and business processes. Similarly, OECD (2017) offers a discussion on how systems approaches can be used by governments to design policy and (among several other examples) describes how the Prime Minister's Office in Finland developed a new framework for experimental policy using the tools from systems approaches. At both the macro and micro levels, systems approaches are increasingly being adopted by practitioners to navigate many of the same challenges of complexity, context, and uncertainty with which academic researchers are also grappling.

These convergences of interest, theory, and method present opportunities for cross-sectoral and cross-disciplinary learning. And while these overlaps of questions and methods do serve as a warning against strawman characterizations of other disciplines, so too can they serve to conceal real differences in the specifics of choosing and combining analytical methods, in how theoretical frameworks are constructed and tested, and – most of all – in the extent to which questions about context and complementarity are prioritized when thinking about policy effectiveness. It is our hope that this article provides readers from a range of backgrounds with a better understanding of the current state of literature on systems approaches, ideas for new avenues of connection with their work, and a common conceptual foundation on which to base dialogue with researchers from different traditions who share the goal of using evidence to improve public service delivery.

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Online Appendix

Review of Systems Approaches in Health, Education, and Infrastructure

July 2023

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1. Introduction

In recent years, the idea of taking a systems approach to understanding public service delivery has gained currency with academics and policymakers alike (OECD, 2017; Bandiera et al., 2019; Besley et al., 2022). This online appendix reviews the state of systems approaches in three sectors where such approaches have been increasingly employed to understand service delivery: health, education, and infrastructure. Systems approaches go as far back as the 1930s (Jackson, 2009), with some of its initial ideas captured by the works of Von Bertalanffy and his General Systems Theory (1972), that was mainly based on the sectors of biology and ecology. This evolved into other sectors such as engineering through cybernetics and systems engineering in the 1940s (Hall, 1962), and later into more quantitative computer modelling approaches leading to the field of systems dynamics (Forrester, 1961; 1968). Around the 1970s, debates around how to capture social elements of the world into systems approaches led to the emergence of *soft systems* approaches (Checkland, 1999), which naturally saw the use of systems approaches in more human-centered sectors such as health and education.

Whereas the main text of the paper takes a synthetic and integrative approach across sectors, in this online appendix we provide a sector-by-sector view on the state of systems approaches in our three focus sectors of health, education, and infrastructure. This appendix will thus be of interest to readers interested in their particular sector or in how the shape of systems approaches differ in other sectors. It also provides readers with a fuller picture of the literature review on which the conceptual argument in the main text of the paper is based.

In compiling this review, two considerations guided our methodological approach. First, the recognition that all three sectors use the language of systems approaches in different ways and

hence the standard use of keywork searches would result in an unbalanced output of relevant studies across sectors. Second, not all studies that use systems approaches self-identify as using these approaches (e.g., Batterham et al., 2022; Masset, 2019).

Based on this, we purposely opted not to conduct a standard systematic review. Instead, we relied on a three-step methodology. First, we reviewed core foundational texts and review papers based on suggestions from experts and carefully traced citations from these texts to develop a basic understanding of the use of systems approaches in each sector.[1] Second, we supplemented this initial search with additional relevant texts through key word searches in google scholar and the Oxford search library SOLO. We used four main types of keyword searches: "systems approach + [sector name]", "systems framework + [sector name]", "systems thinking + [sector name], and "systems methodology + [sector name]". Third, we used the citations and reference lists of these texts to identify additional articles of interest, stopping when we reached a point of saturation with respect to the type of concepts and methods being deployed. Throughout the review and synthesis process, the authors discussed emerging patterns, themes, gaps, and ambiguities with each other, iterating between conceptual synthesis and refinement on the one hand and extending the net of the literature search more widely on the other.[2] We applied this three-step methodology flexibly across the three sectors, and in

[1] We consulted several experts early in our review process for each sector, after having done initial background work on each sector, in order to help us identify foundational texts and help ensure we were not missing whole areas of literature. We consulted Seye Abimbola, Lucy Gilson, and Kara Hanson for health; Lant Pritchett for education; and Jim Hall for infrastructure. An initial background paper with a review across the three sectors was also shared with 39 experts across health, education, infrastructure, and public administration as part of a workshop titled "Systems of Public Service Delivery" organized by the authors on March 14th-15th, 2018 in Oxford. This (along with other conference/workshop presentations and individual feedback highlighted in our acknowledgments) helped in identifying additional relevant texts.

[2] Two examples of the nature of ambiguities we addressed are as follows: a) Is a study systems approaches or not? This was the main ambiguity that we discussed in early stages of our analysis. We identified two types of studies that had a systems focus – one set of studies focused on the whole system and approached the design of their research with a systems lens (i.e., the authors developed the theory and empirical approach with a focus on issues of context and relationships between various system components), whereas a second set of studies focused on the whole system but the design of the research did not include a systems lens. Based on our discussions, we decided to include the former in our analysis and made a distinction between studies that are systems focused in "approach" versus systems focused in "substance" respectively. b) Is a macro-systems

doing so also came across and reviewed non-sector-specific work on systems approaches to understanding service delivery in complex and unpredictable systems more generally. We include in our review texts that self-describe as systems-based, as well as many which share similar questions, theoretical approaches, and empirical methods but which do not necessarily adopt the language of systems approaches. The result is not a systematic review in the formal sense of the term, but nevertheless provides a detailed and consistent picture of the state of the literature in each sector.[3]

Given the diversity and range of systems approaches in these sectors, we organize our review by two types of systems approaches within each sector: macro-systems approaches and micro-systems approaches. The former are primarily concerned with looking at the entire system as a whole, and the use of systems approaches to understand the collective coherence of a set of policy interventions with each other as well as various other elements of context. The latter focus in on a single policy intervention, with emphasis on the use of systems approaches to understand not only whether the policy in question works, but also how it interacts with other elements of the system.

framework inventory or relational? We often came across cases where it was not obvious whether a macro-systems framework was inventory or relational. For example, Van Damme et al. (2010) characterised a health macro-systems framework by listing 10 different operational elements at the macro, meso, and micro level. The authors did not specify relationships between the 10 different system elements but included some directional arrows between the macro, meso, and micro level. We discussed such cases and concluded that we would only characterise a macro-systems framework as relational if: a) the main focus of the framework was to specify relationships between system elements; and b) the authors specified relationships between at least half of the system elements. Based on these criteria, Van Damme et al. (2010) is listed as an inventory framework in our paper.

[3] While it is common for systematic reviews to provide statistics on the number of articles consulted and number of articles coded for inclusion in the study, these figures are less relevant for our more flexible methodology. This is because our systematic keyword and database search was only one component of our methodology, alongside our more targeted use of existing literature reviews, expert input, and snowballing from reference lists. Together, these yielded approximately 300 articles, books, slides, policy reports, and other documents that fit our description of systems approaches (or were closely related) and that we read in detail – some of which are themselves reviews that encompass many more sources. However, we include this figure merely as an indication of the extensive nature of our review, while emphasizing that this figure should not be compared to the type of statistics typically reported for systematic reviews, nor does it represent the total number of studies using systems approaches.

Section 2 reviews the state of the systems literature in the health sector, followed by the education and infrastructure sectors in Section 3 and Section 4.

2. Health Sector

2.1 Motivation, Definition, and Scope

Health systems research developed as a field over more than decade ago as a way to understand complexities, interrelationships, and structural constraints within health systems. Limited success of emergency responses to major health epidemics around the world (such as the West African Ebola outbreak in 2012-2014) underscored the need for coordinated action across various system actors such as policymakers, health service providers, health recipients, whilst taking various contextual realities into account. In addition, the sluggish progress of key health indicators around the world despite significant investments in a range of narrow interventions brought attention towards structural weaknesses in health systems (Travis, 2004; WHO, 2007). These factors highlighted the urgency for research focused on health systems.

The World Health Organization (2007, p. 2) defines a health system as consisting of "all organizations, people and actions whose primary intent is to promote, restore or maintain health." The Alliance for Health Policy and System Research (2011), a health systems research forum initiated by the World Health Organization (WHO) in collaboration with the Global Forum for Health, defines *health systems research* (HSR) as the production of knowledge that is geared towards understanding how societies organize themselves to achieve health goals.[4] This definition implies a focus on how the 'whole' system functions instead of a narrow focus

[4] The Alliance for Health Policy and System Research (AHPSR), comprising of health practitioners and academics from around the world, has taken instrumental steps in defining the scope, boundaries and agenda of the field through several publications.

on any single aspect of its individual components (Hanson, 2015).[5]

Three key features summarize the scope of systems research in this field. First, health systems research has a specific focus on real world issues. It aims to address questions which are practically faced by countries within the health sector. Second, it is multidisciplinary drawing on disciplines such as economics, sociology, anthropology, political science, public health, and epidemiology. This is closely linked to the first point as real-world issues about health systems could be of the 'why', 'what', and/or 'how' nature. Hence the disciplinary or methodological grounding of research is determined by the question of interest. Third, the research is applied with a unique focus on policy with the goal to influence policy. This implies that research with respect to how policy is made and implemented is a key area of research focus for the field (Mills, 2012; Gilson, 2012).

2.2 Macro-systems Approaches

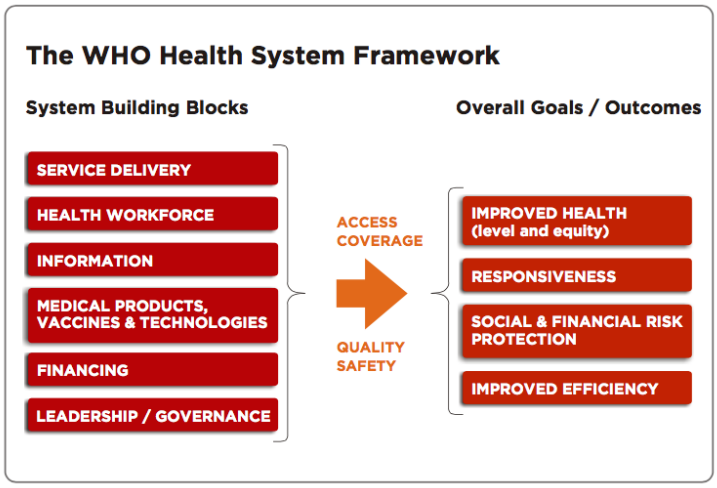
Macro-systems approaches in HSR focus on "whole" systems that aim to understand coherence, coordination, and interconnection of various policies within systems. These approaches vary in the level of specificity with which they define relationships between health system components. In this sub-section, we illustrate this variation through a range of different examples.

One type of macro-systems approaches merely describe health system components in different ways, such as in terms of its functions, stakeholders involved, or hierarchical levels. The

[5] The Alliance included the word 'policy' in what is commonly known as health systems research and renamed it to 'Health Policy and Systems Research (HPSR)' to capture two key facets of the field which do not clearly come through in the definition – first to highlight the importance of social and political realities within a health system and second, to recognize the applied, policy, and question-driven nature of the field.

seminal WHO framework defines the health system as comprising six key functional building blocks - service delivery, health workforce, information, medical products (including both vaccines and technologies), financing, and leadership and governance – and links them to the broader health system goals (WHO, 2007).

Figure 1: WHO Health System Framework



Source: De Savingy and Adam (2009)

Frenk (2010), on the other hand, defines the health systems in terms of its stakeholders. He identifies patients, consumers, and tax-payers as key players in his health system framework and outlines how the health system operates through these stakeholders as the main sources of financing and co-producers of health. Fulop et al. (2001) and Van Damme et al. (2010) characterize the health system in terms of its level of operation. They identify three different levels - macro, meso, or micro. As per their framework, macro includes the national and international context which determines policy such as resource allocation and financing policy, meso involves the local health system and/or the organizational level which determines how policy gets implemented, and micro involves the people in the system (both patients and providers).

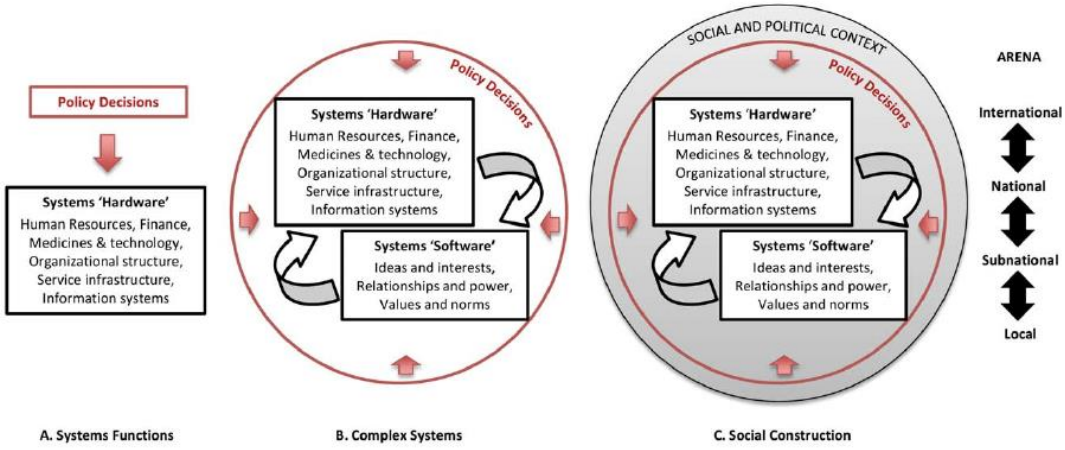
Another class of macro-systems frameworks are more analytical in their objective, with an additional focus on specifying relationships within the system. These frameworks tend to specify the form of the relationship between system elements either in a generalized way (through indicating which elements of the system are interlinked or not linked) or in a specific way by drawing on theories to define the nature of relationships. For example, Frenk (1994) identifies the state, health providers, and the population as key components within a health system, with a series of arrows showing how these actors are linked. He argues that the relationship between providers and the population does not occur in isolation but is rather shaped by the organizations in which they operate, the heterogeneous nature of the organizations and the population, and the state through setting policies of regulation and financing. While the author theorizes how and why these relationships exist, he does not employ specific theories to explain the nature of these relationships.

On the other hand, Gilson (2003) characterizes the health system through relationships between patients and providers, and defines the relationship through very specific 'trust' flows. She argues that the behaviours of health system providers and patients are directly influenced by trust between the patient and the provider, and trust between the health agent and the wider institution.

The work of both Frenk (1994) and Gilson (2003) points towards the need for considering the software (i.e. institutional environment, values, culture and norms) in addition to the hardware (i.e. population, providers, organizations) of a health system in order to understand the dynamics at play. In line with their arguments, Sheikh et al. (2011) propose a model which

builds in such software into the existing 'building blocks' of health systems as proposed by the WHO (2007). They argue that in addition to the WHO building blocks, the values, norms, ideas, and power dynamics play a critical role in how relationships between different system elements are shaped.

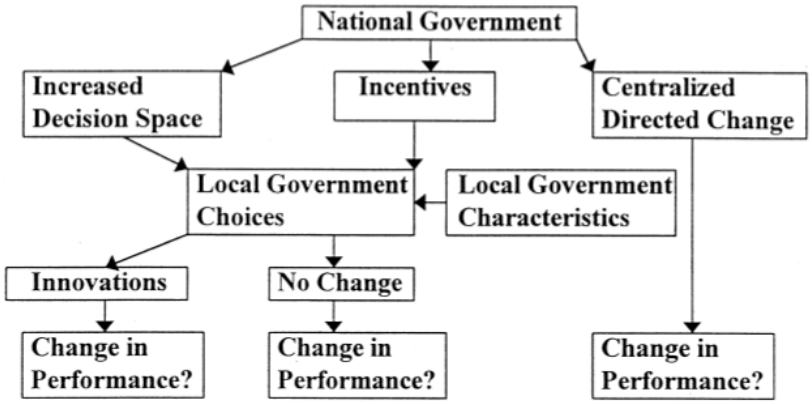
Figure 2: Health System Hardware and Software



Source: Sheikh et al (2011)

Often frameworks tend to focus on a sub-system to characterize relationships between different system components. Kutzin (2000), for example, develops a macro-systems approach focused on health financing. He outlines the various financing system functions in health financing including revenue collection, pooling of funds, purchasing of services, and provision of services to identify specific policy levers for the government to improve access to health finance. Similarly, Bossert (1998) develops a framework to study decentralization in health systems across countries. He uses the principle-agent model as his basis and extends the model through what he calls the 'decision space approach' to understand the degree of choice transferred from the center to local authorities and the impact of this choice on performance.

Figure 3: A Decision-Space Approach for Studying Decentralization



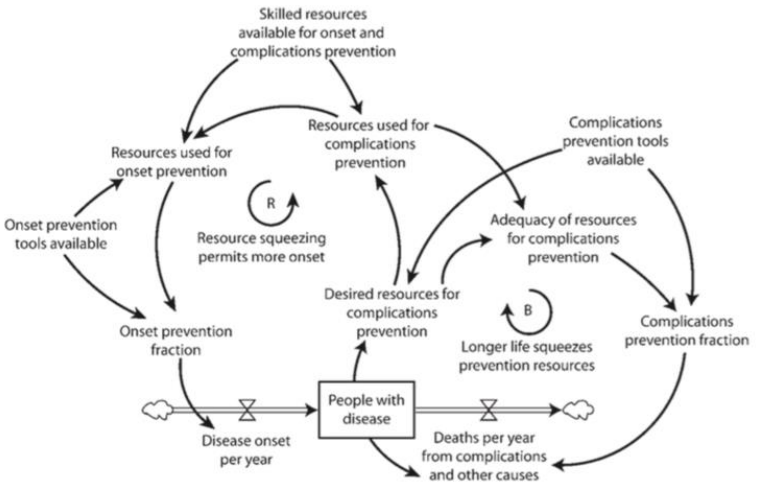
Source: Bossert (1998)

A final set of macro-system approaches use very specific numerical values to characterize relationships between system components, such as through the use of systems modelling, systems dynamics, and causal loops. While research in formal modeling of health systems continues to grow, the effectiveness of such models tends to be limited to their predictive ability instead of being able to study the actual impact of large-scale interventions (Hanson 2015).

For example, Homer and Hirsch (2006) develop a causal diagram of how chronic disease prevention works and then use systems dynamic methodology (grounded in concepts of accumulation and feedback loops) to develop a computer-based model to test alternate policy scenarios that may affect the chronic disease population (see Figure 4). Rwashana et al. (2009) use dynamic synthesis methodology (DSM) to model sub-systems within the immunization system (parental participation sub-system and healthcare sub-system). They use this model to explain uptake of immunization in Uganda. Another example is Batterham et al. (2002) where the authors use concept mapping to understand GP integration across primary and secondary health care systems in Australia. They develop a typology and model of GP integration using concept mapping in 11 groups of GPs, consumers, and other practitioners and then test it through confirmatory factor analysis. Bishai et al. (2014) explore how a hypothetical policy

change of funding curative versus preventative services might lead to unintended consequences through complex relationships between stakeholders and financial resources. They identify several negative feedback loops that lead to stable model equilibria that were unexpected from the objectives of the original policies.

Figure 4: A simple model of chronic disease prevention



Source: Homer and Hirsch (2006)

2.3. Micro-systems Approaches

Micro-systems approaches in health aim to answer questions with respect to how a specific policy is designed, implemented, evaluated, and scaled-up (Mills, 2012; Gilson, 2012; Hanson 2015), with a specific focus on how policies interact with other system components. The research draws on a range of disciplines and methodologies to address these questions. In this sub-section, we illustrate these approaches.

Given health systems researchers often deal with complex policies and interventions that interact with various elements of the system and context in different ways, a key question for HSR is how to think about research and evaluation design, measurement of outcomes, and process evaluation whilst accounting for these interactions (Hawe, 2015). To address these set of concerns, the field has seen a rise of 'realist evaluations' as a way to evaluate complex interventions to tease out causal relationships. This technique recognizes that many different variables may be interwoven which interact in different ways with the fabric of society. Hence, the aim is to identify 'what works in which circumstances and for whom?', rather than merely 'does it work'? (Pawson and Tilley, 1997). More specifically, instead of looking at simple cause and effect relationships, realist research considers the interaction between context (the specific setting in which an intervention is rolled out), the mechanism (process of how an intervention works) and outcome (C-M-O). It develops 'middle range theories' through developing context-mechanism-outcome relationships which show how an intervention works (Greenhalgh et al., 2016).

While such evaluations have been rising in the field, their uptake has been slow due to lack of clarity around the methodology, lack of guidance on its use, and its time-consuming nature (Marchal et al., 2012). Despite these challenges, some researchers have been able to leverage the methodology effectively to tease out important insights. For example, Mac Kenzie et al. (2009) use realist evaluation techniques along with a clustered randomization trial to understand the impact of a nutritional intervention during a smoking cessation programme. The authors argue that using realist approaches helped them build a more refined understanding of how outcomes and processes were related. While Mac Kenzie et al. (2009) combine realist approaches with a rigorous experimental design, a lively debate continues on whether realist approaches can be used together with experimental and quasi-experimental approaches. While

proponents argue that realist approaches can be integrated with RCTs by focusing on standardizing processes and functions of interventions (Hawe et al., 2004; Bonell et al., 2012), others argue that given RCTS are fundamentally based on a positivist paradigm, they would be unable to fully adapt to capture the complexity of interactions.

In addition to realist evaluations, evidence aggregation techniques such as meta-analysis and systematic reviews are also used in HSR. Leviton (2017), for example, argues that systematic reviews and meta-analyses can offer bodies of knowledge that support better understanding of external validity by identifying features of program theory that are consistent across contexts. To identify these systematically, she identifies several techniques to be used in combination with meta-analyses such as a more through description of interventions and their contexts, nuanced theories behind the interventions, and consultation with practitioners.

Health systems researchers are also beginning to rely on an evidence aggregation method called *realist synthesis,* which relies on the realist philosophy. The key idea is to aggregate evidence along the context, mechanism, outcomes outline (C-M-O) to identify not only the average treatment effect, but also how an intervention was intended to work (Wong et al., 2013). Abimbola et al. (2019), for example, carries out a realist synthesis of decentralization interventions to understand why, how, and in what context decentralization effects health system equity, efficiency and resilience. The author identifies three mechanisms which may mediate the effect of decentralization on health outcomes: 1) 'Voting with feet' which captures how decentralization affects patterns of inequities in a jurisdiction; 2) 'close to ground' which captures how local governance allows for local initiative, input, feedback; and 3) 'Watching the watchers' which captures the mutual accountability links between the citizens and the government. Greenhalgh et al. (2016) conduct a realist review to understand how community

pharmacies support smoking cessation. Their review identifies five mechanisms that could support success or failure of pharmacy-led smoking cessation programmes - pharmacist identity, pharmacist capability, pharmacist motivation, clinician confidence, and public trust.

Understanding gaps in policy implementation is a key focus of health systems research (WHO 2002; De Savingy and Adam 2009). For example, Sheikh and Porter (2010) conduct a stakeholder analysis to identify key gaps in policy implementation. They use data from 46 in-depth interviews with various stakeholders across 5 states India to understand bottlenecks in HIV policy implementation (from 9 hospitals selected by principles of maximum variation). Using the "framework" approach for applied policy analysis, combining inductive and deductive approaches, they find that key gaps in policy implementation included conflicts between different actors' ideals of performance of core tasks and conformance with policy, and problems in communicating policy ideas across key actors involved in implementation.

Another method that health systems researchers rely on is ethnography and participant observations, especially when the question of inquiry involves complicated relationships between different system actors and elements. For example, accountability relationships between different health system actors are central to health service delivery, but capturing the complex social and political realities around such relationships requires techniques which allow deeper exploration. For example, George (2009) conducts an ethnographic analysis to understand how social dynamics may create individuals own meaning of accountability. He examines routine human resource management and accountability practices in Koppal state, India, showing how a complex web of social and political relations among different actors in primary health care influences local understandings and channels of accountability.

Systems research often has a specific focus on the implementation, uptake, and scale-up of policy (Hanson, 2015). The discipline of *implementation science* in the health sector is specifically targeted towards understanding such issues (Rubenstein and Pugh, 2006). The discipline has been defined as "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services" (Eccles and Mittman, 2006). Greenhalgh et al. (2017), for example, combine qualitative interviews, ethnographic research, and systematic review to study the implementation of technological innovations in health. They develop the non-adoption, abandonment, scale-up, spread, and sustainability (NASSS) framework to both theorize and evaluate the implementation of health care technologies. Research in implementation science is at times less concerned with the question of what is effective (where there is strong prior evidence on an intervention's efficacy in ideal conditions) and is more concerned with how to implement effectively. For example, there is a comparatively large body of research on evidence-based treatments in mental health services, but their adoption and implementation in practice remains a challenge (Procter et al., 2009).

Discrete choice experiments are a methodology that have been adopted by systems researchers to understand questions such as patient preferences for different aspects of a treatments and health worker job preferences (Ryan, 2009). This has enabled researchers to develop clarity on these questions, within a single context as well across several contexts, in a cost-effective way. For example, Blaauw et al. (2010) use discrete choice experiments (DCEs) to evaluate the effectiveness of different policies in attracting nurses to rural areas in Kenya, South Africa and Thailand. They find that in Kenya and South Africa, better educational opportunities or rural allowances would be most effective in increasing the uptake of rural posts, while in Thailand better health insurance coverage would have the greatest impact. Such approaches are also

helpful in developing a system-wide understanding of central questions such as job preferences which is essential for understanding how to allocate limited resources to achieve health gains.

In response to the complexity in systems and interventions, some systems researchers rely on methods that allow for more iterative experimentation and learning. For example, Tsofa et al. (2017) use a 'learning sites' approach in which a geographical space is specifically created where researchers and health system practitioners work together over long periods of time to uncover and address thorny governance challenges. As part of the learning site activities, formal reflective sessions are regularly held among researchers, between researchers and practitioners, and across learning sites to develop an in-depth contextual grounding to study complicated pathways to change. Using this approach, the authors study the impact of a new decentralization reform in Kenya on health resource allocation and budgeting. They conclude that the decision space, organizational capacity, and accountability structures are critical to achieving decentralization success.

3. Education Sector

3.1 Motivation, Definition, and Scope

Education systems research emerged with the growing recognition that significant investments in various inputs such as textbooks, hiring of new teachers, and increased salaries of teachers have not had the effects that governments and researchers hoped for in terms of improvements in learning outcomes (Banathy, 1991; Betts, 1992; Glewwe and Muralidharan, 2015; World Development Report, 2018).[6] In some of the early works on education systems research,

[6] For example, Indonesia doubled teacher wages incurring an expenditure of nearly 4.5 billion USD which produced near-zero impact (De Ree *et al.,* 2015). Similarly, research from India and Africa shows that reduction in class-sizes does not always produce the desired impact if other systemic features such as teachers, incentive structures, and curriculum do not change (Pritchett, 2015).

Banathy (1991) argued that a new systems framework for creating educational change was needed in light of the changing demands of societies and the needs of various stakeholders within a system. More recently researchers and practitioners are increasingly recognizing that the current global 'learning crisis' requires addressing system weaknesses and making the whole education system coherent with learning (Pritchett 2015; World Development Report, 2018). This has brought a greater emphasis on understanding the interdependencies between various features of an education system such as institutions for governance, accountability, information, financing rules, and school management (World Bank, 2014; World Development Report, 2018).

Moore (2015, p. 1) defines education systems as "institutions, actions and processes that affect the 'educational status' of citizens in the short and long run." In line with some of the early calls to adopt a systems lens for understanding education reform (Banathy 1991; Betts, 1992), several global institutions are making strides towards undertaking education systems research. For example, a World Bank initiative called Systems Approach for Better Education Results (SABER) was launched in 2011 with the goal to collect data on system capacities and gaps through a range of survey tools designed for each education sub-system. The Research on Improving Systems of Education (RISE) programme is another example of a research program focused on education systems research. RISE is a multi-country programme that was initiated in 2015 with research in Pakistan, Ethiopia, India, Tanzania, Indonesia, and Vietnam. The programme aims to conduct empirically and theoretically well-founded interdisciplinary research to understand how education systems function. Another example of a research programme that takes a systems approach is the Raising Learning Outcomes in Education Systems (RLO) research programme funded by the Foreign, Commonwealth & Development Office (FCDO) and the Economic and Social Research Council (ESRC). The programme

focuses on interactions between different education system components and the various contextual features that affect educational reform.

The scope of education systems research has close parallels with health. Pritchett (2015b) and Hanson (2015) outline the following key features of education systems research. First, it aims to be 'question-driven' which employs various disciplines as per the need of the question. For example, systems research in education could explore questions ranging from the impact of a national teacher training intervention through mixed methods to questions about how power and accountability structures in the education system function through ethnographic accounts drawing on various disciplines such as economics, political science, sociology, and anthropology. Second, the questions focus on real-world issues which either pertain to the system as a whole or a specific sub-component. For example, while questions about national teacher recruitment or training policy would be relevant for the teaching system sub-component, questions about a specific teacher training programme in 10 selected villages by a specific NGO would not be relevant as they would not have any implications for the teaching system or the education system as a whole. Third, systems research in education aims to explore questions which relate to learning gains. Fourth, it studies reforms which have the potential for scale and fit the context of the specific region.

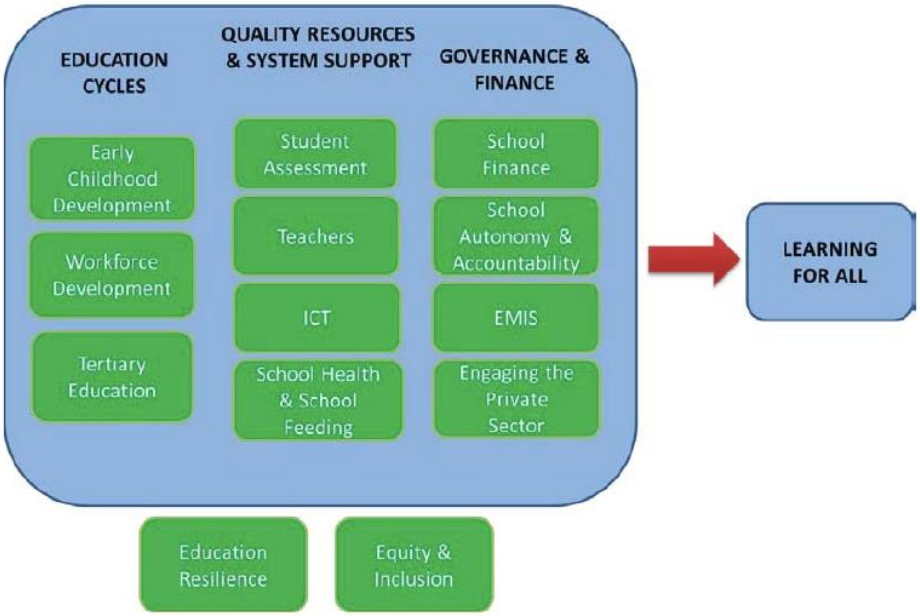
3.2 Macro-systems Approaches

Similar to health systems research, macro-systems approaches in education also vary in the specificity with which they define relationships between system components. In this sub-section, we outline a range of macro-systems approaches in education systems research.

Some macro-system approaches define different components within an education system,

without specifying relationships between different sub-components. Such approaches in education systems research have often been used as a foundation for designing survey tools for system diagnostics. For example, Systems Approaches for Better Education Results (SABER) at the World Bank describes the education system in terms of 13 different functions (Halsey and Demas, 2013).

Figure 5: Domains of Education System (SABER)



Source: Halsey and Demas (2013)

SABER has implemented its system diagnostic tools in more than 100 countries to identify key constraints to system effectiveness (World Bank, 2014). In Jamaica the government's Early Childhood Commission employed the SABER dataset to draft its new National Strategic Plan as well as a national multi-sector early childhood development policy. Similarly, in Tanzania, information from the diagnostic supported the Government to plan its education reforms (World Bank, 2014). Country teams in RISE have also adapted these tools locally to develop clarity on how various sub-components in the education system contribute to (or hamper) system effectiveness. Pritchett (2018) highlights key insights and challenges of using such system diagnostics. He argues that input indicators and de jure (formal) policies which these

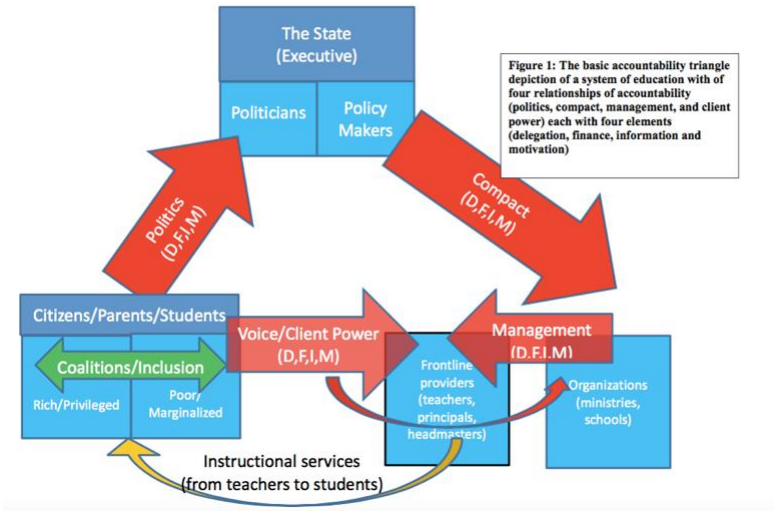
tools aim to capture do not always explain learning - for example, Vietnam shows high learning scores in PISA assessments but indicators in the system diagnostic tools are unable to explain this success. He argues that to understand the drivers the system effectiveness, it is essential to develop and implement tools which in fact aim to capture *de facto* (i.e. actual) policies. At the same time, he acknowledges that developing and implementing tools that capture *de facto* policies can be challenging.

Another macro-systems framework which is descriptive in nature is the General Education Quality Analysis Framework (GEQAF). This framework defines 5 components of the education system, with each component catering to a specific impediment to learning: 1) supporting mechanisms (which includes governance, financing and system efficiency); 2) core resources (which includes curricula, learners, teachers and the learning environment); 3) core processes (which includes learning, teaching and assessment); 4) desired outcomes (which includes competencies and life-long learning; and 5) development goals (which includes relevance and equity) (UNESCO, 2012). While these frameworks go in a fair degree of descriptive detail, they do not specify how different components of the education system are related to one another.

Some macro-systems approaches in education systems research specify relationships between system components. For example, Pritchett (2015) describes the education system components and the relationships between them through very specific accountability relationships. He describes the education systems as a composition of the following actors - the executive apparatus of the state which makes key decisions (laws, regulations, policies and the allocation of budgets); organizational providers of schooling such as schools and organizations that control and manage the schools; teachers who are the "front-line service providers"; and

citizens/parents/students who are the intended beneficiaries of schooling. He defines the relationships between these different actors as 'accountability' links which act through four design elements– delegation, financing, information, and motivation. He argues that the system of education works when there is an adequate flow of accountability across the key actors in the system across these four design elements (see Figure 6).

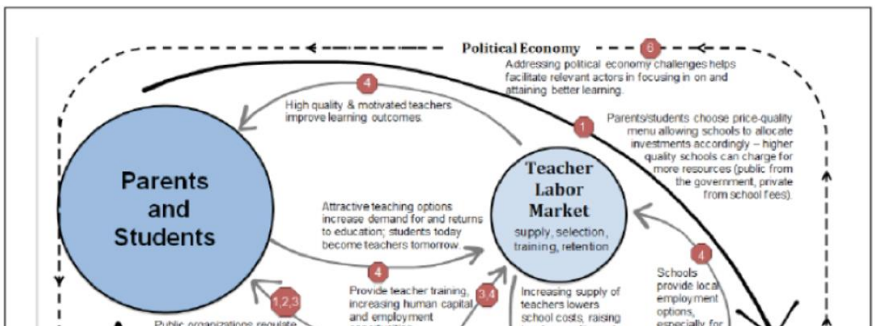
Figure 6: Accountability Triangle in the Education System



Source: Pritchett (2015)

Similar to Pritchett (2015), Andrabi et al. (N.D.) also describe the relationships within the education system through specific relationships. They describe the Pakistan education system as an economic market with key constraints and frictions along five dimensions: 1) access to information; 2) access to resources and financing; 3) knowledge and innovation markets; 4) labor market incentives; and 5) regulatory and governance structure. They argue that the functioning of the education system hinges on being able to address key frictions in the market along the above-mentioned dimensions (see Figure 7 below).

Figure 7: Market Frictions in the Education System



Source: RISE Pakistan Technical Proposal

Similar to the health sector, education systems researchers are also starting to model education systems where relationships between system components are defined through very specific numerical relationships. For example, Kaffenberger and Pritchett (2021) develop a structural model to capture the dynamics of learning. Using existing empirical literature to assign numerical values to the parameters in their model, they predict how learning outcomes would be affected under different policy scenarios such as expanding schooling to universal basic education, slowing the pace of curriculum, and increasing instructional quality.

3.3 Micro-systems Approaches

Micro-systems approaches in education systems research are characterized by a focus on not only what works, but also how and why (Magrath et al., 2019). Given this focus, they tend to rely on a combination of quantitative and qualitative methods to understand whether, how, and why specific policies work, often comparing their impacts across contexts.

Magrath et al. (2019) highlights several projects under the Raising Learning Outcomes in Education Systems (RLO) research programme funded by FCDO and the ESRC where researchers are using mixed-method approaches to diagnose questions such as how

pedagogical reform takes place or how accountability relationships function. For example, Lynch et al. (2018) use a mixed-methods study following the guidelines from the the Medical Research Council (MRC) Framework for Developing and Evaluating Complex Interventions (Craig et al., 2008) to design and test the feasibility of a training programme for developmental stimulation of children with visual impairment in Malawi. Using qualitative interviews to guide the initial training design, the researchers used a combination of quantitative data from logbooks along with in-depth interviews to assess the fidelity of implementation, as well as insight into outcomes that needed to be measured to understand the impact of such training programmes. In another example, Aiyar et al. (2015) combine qualitative interviews with quantitative time-use data of the public education officials in Bihar to understand how a new pedagogical reform works. Their study highlights that organizational culture plays in instrumental role in how reforms are perceived and implemented by frontline workers

Over the last two decades, the education literature has also explored a series of system-level questions through experimental and quasi-experimental techniques. Although surveying the full range of these studies is outside the scope of this review, they include understanding the impact of large spending by governments (in the form of textbooks, cash transfers), governance reforms such as teacher incentives or community monitoring programmes, new pedagogical approaches in government schools (such as contract teachers or literacy and numeracy skills lessons), and the impact of school-based management reforms (see Glewwe and Muralidharan, 2015 for a review of studies). Many of these experimental studies design multi-arm-controlled trials to look for interactions between arms of a policy and other features of policy context in an effort to understand theoretical mechanisms. For example, Andrabi et al. (2018) design a multi-arm intervention to test the impact of alleviating financial constraints for private schools. The variations in treatment arms, by providing cash transfers to either one private school in the

village or all private schools in the village, allow the researchers to understand how financial constraints interact with the overall market structure.

With the surge of experimental and quasi-experimental studies in the education sector, there has also been a focus on methods of evidence aggregation such as meta-analysis and systematic reviews (Conn, 2014; McEwan, 2015; Evans and Popova, 2016 to name a few). These reviews, which have largely focused on identifying average treatment effects of interventions across contexts, have also at times pointed to concerns of external validity and how similar interventions can have very different effects across contexts or when scaled up (Pritchett and Sandefur 2015; Bold et al., 2016; Masset, 2019). For example, Masset (2019) calculates prediction intervals for various meta-analyses of education interventions and finds that interventions' effectiveness is highly heterogeneous and unpredictable across contexts, even for simple interventions like merit-based scholarships.

Similar to the health sector, education systems researchers also tend to rely on the methodology of realist synthesis to understand how interventions work. For example, Eddy-Spicer et al. (2016) conduct a realist synthesis to understand how school accountability policies (such as assessments, monitoring, and inspections) operate locally in schools in low- and middle-income countries to improve student learning outcomes. The findings highlight that improved student learning outcomes tend to be associated with stronger support structures for school leaders and staff in how accountability policies are implemented.

One type of qualitative methodology used by education systems researcher is ethnography and participant observation. For example, Bano and Oberoi (2020) use ethnographic methods to understand how innovations are adopted in the context of an Indian NGO that introduced a

Teaching at the Right Level (TaRL) intervention, and tease out lessons for how innovations can be scaled and adopted in state systems. Watkins and Ashforth (2019) aim to understand norms and practices around schooling by observing interactions between parents, teachers, and administrators in rural Malawi at the grassroot level. Using narratives from the Malawi Journals Projects, interviews in the study, and participant observations, the researchers highlight how issues of accountability at the school-level are resolved on a daily basis.[7]

Education systems researchers often rely on large longitudinal quantitative datasets to answer questions about specific policies. For example, Young Lives is a longitudinal study of 12,000 students across the countries of Ethiopia, India, Peru and Vietnam covering a life span of 15 years. This project has created a rich longitudinal household and student learning dataset overtime which has allowed the team to explore important policy questions with a systems lens. For example, in India the household surveys and learning data have together shed light on the role played by low-cost private schools within the education system.[8]

Practitioners and researchers in education are also increasingly focusing on complexity in education systems, and the set of strategies that may be required to account for this complexity when designing educational reform (Snyder, 2013; Crouch and Destafano, 2017). Snyder (2013) draws on complexity theory and its applications to health and ecology, and argues how principles of complexity theory can be applied to educational reform. Crouch and DeStefano (2017) propose a strategy for intervention design and evaluation that relies on the strategies of

[7] The Malawi Journals project is an account of narratives written by individuals from rural Malawi from 1999-2015. See details here: https://deepblue.lib.umich.edu/handle/2027.42/113269
[8] https://www.younglives.org.uk/content/education

'Doing Development Differently (DDD)' which rely on local-level problem identification and problem-solving, involving a process of iteration and adaptation.[9]

Within the education sector, several research efforts try to understand the management, governance, and performance of education systems at a more macro-level through the use of micro data. These research efforts are hard to classify into our macro and micro systems research classification, but serve as unique examples of research that tries to bridge these two types of research. For example, education system researchers often rely on large longitudinal quantitative datasets that rely on micro data to answer questions about how education systems function. For example, Young Lives is a longitudinal study of 12,000 students across the countries of Ethiopia, India, Peru and Vietnam covering a life span of 15 years. This project has created a rich longitudinal household and student learning dataset overtime which has allowed the team to explore important policy questions with a systems lens. For example, in India the household surveys and learning data have together shed light on the role played by low-cost private schools within the education system (Rossiter et al., 2018).

On the other hand, Adelman et al. (2021) have developed a new instrument called the Education System Coherence Survey (ESCS) that aims to understand coherence in the understanding of task allocation of bureaucrats across the education delivery chain. One of the measures that can be constructed from the instrument is an incoherence index that captures the gap between *de jure* task allocation and bureaucrats' *de facto* understanding of task allocation, allowing researchers to explore how such incoherence at different levels of the education system may be related to student learning outcomes. This survey has been implemented across four LAC

[9] The DDD strategies relate closely the 'Problem Driven Iterative Adaptation' approach proposed by Andrews et al (2013)

countries—Brazil, the Dominican Republic, Guatemala, and Peru. Another example is the work of Levy et al. (2018) that explores the performance of education systems as a whole, but with a focus on politics and institutions. The authors present a multi-level framework where incentives and constraints at the national level shape incentives and constraints at various sub-national levels of the education bureaucracy, ultimately cascading down to schools. Applying the framework to the context of two South African provinces, where there is significant delegation of education service delivery to provinces and schools but variation in provincial-level political dynamics, they explore conditions under which horizontal and/or hierarchical models of governance work.

4. Infrastructure Sector

4.1 Motivation, Definition, and Scope

Systems research in infrastructure is conducted with the primary aim to understand and manage complex interactions within and between various infrastructure sectors. Research in this sector can be clearly demarcated into two categories where each has its own motivation and objective: 1) sector-specific system analyses which allows taking a systems approach within a specific type of infrastructure sector (e.g. water, electricity, or gas); and 2) systems-of-systems analyses where research is conducted across various infrastructure sectors to explore relationships between infrastructures sectors, infrastructure risk, and long-term systems-of-systems analyses. While the former is considerably well-established, the field of system-of-systems analyses is relatively new (Hall et al. 2016).

Sector-specific system analyses are motivated by the idea that specific infrastructure sectors can be made more efficient by understanding feedbacks between various system components, and managing their demand accordingly. A systems-of-systems approach takes account of the

cross-sectorial interdependencies between different infrastructure sectors and is motivated by two key needs that infrastructure systems face today. First, the need for adequate planning for future operation, capacity, and environmental performance of infrastructure systems in light of future socio-economic changes such as population changes, per-capita infrastructure demands, and economic growth. Second, the need to ensure resilient operation of infrastructure services in the face of increasing climate and socio-economic risks. These challenges are exacerbated by the fact that infrastructure networks have become increasingly interdependent, providing potentials for knock-on effects causing major economic and societal disruptions. For example, a power failure in a major electricity exchange can result in the temporary loss of broadband service for hundred thousand of households and businesses (BBC 2011). Hence, systems-of-systems approaches for short-term risk analysis aim to reduce the risk of cascading infrastructure failures, allow for more effective responses, and improved coordination (Dudenhoeffer et al., 2006).

A specific infrastructure system can be defined in several ways depending on the type of infrastructure or the scope of research analysis. While generally infrastructure systems are understood as various interdependent physical and socio-economic systems to distribute essential services, (Bissell, 2010), another approach to define infrastructure systems is through the types of assets within the system which can include energy, transport, water, waste, information and communications technology (ICT), social infrastructures (hospitals, schools, etc.), financial services, and the built environment (Cabinet Office, 2010). Analysis of infrastructure at a system level requires integration of various components – such as across different scales (e.g. urban, rural, or regional), across eco-systems (e.g. social, urban, land, water and climate), and between different structures or sectors (e.g. social, physical, health, economic and political). Following this, Hall et al. (2016, p.6) develop a definition of

infrastructure systems as ‘the collection and interconnection of all physical facilities and human systems that are operated in a coordinated way to provide a particular infrastructure service.”

Infrastructure systems research is used to understand current infrastructure performance (for example, whether different infrastructure sectors currently meet demand, environmental standards, resilience criteria), predict future infrastructure needs, and to understand the impact of newly built infrastructure assets on the entire system. The scope of systems research in infrastructure has several commonalities with the health and education sectors. First, it has a real-world focus, where approaches and methodologies for system assessments of infrastructure are direct real-world problems of planning, designing, and operating infrastructure. Second, it tends to be multi-disciplinary. While the bulk of analysis in the field includes quantitative modelling, it often combines qualitative approaches such as simulation modelling with decision science, policy and governance research, and adaptive pathways. Third, it focuses on directly impacting policy. For example, a number of infrastructure assessment methodologies inherently include adaptive pathways and policy recommendations.

4.2 Macro-systems Approaches

Macro-systems approaches in infrastructure systems research help policymakers and researchers understand how the entire system functions. This helps answer questions such as whether governments should make a large investment in an infrastructure asset or how to manage risks of infrastructure failures. Given these are high stake concerns for governments,

macro-systems approaches in the infrastructure sector mostly include models with tightly specified numerical relationships that can make accurate predictions.

These tightly specified models tend to characterize relationships between different system components through what the infrastructure sector calls *'interdependencies'*. Researchers have adopted descriptive approaches to identify a range of such interdependencies. For example, Rinaldi et al. (2001) outline that interdependencies depend on the scope of the framework and can be classified as a) physical (material or physical flow from one entity to another); b) cyber (information transfer); c) geographical/spatial (physical proximity affecting components across multiple infrastructure systems); or d) logical (dependencies other than the above three categories). Dudenhoeffer et al. (2006) further expand these classes to include two additional categories: a) policy/procedural which includes the effect of a policy or a procedure of one infrastructure on all other social and economic sectors; and b) societal which captures the effect of all influencing factors such as public opinion, confidence, fear, or cultural issues from one system component to another. These different types of interdependencies tend to form the basis of how relationships between different system components within an infrastructure system are characterized.

To developed models of infrastructure systems (that rely on these interdependencies), the literature proposes several different approaches (Ouyang, 2014; Saidi et al., 2018; Dudenhoeffer et al., 2006; Xiao et al., 2008), that can be classified into five broad categories - system dynamic-based approaches, agent-based simulation and modelling, input-output models, network-based approaches, and empirical approaches. A growing number of studies suggest that the current infrastructure system is most suitably modelled using a network-based approach of nodes and edges, which capture essential interdependencies and indicate the flow

of directionality across infrastructure assets (Lewis, 2006). While no network modelling approach can answer all the questions (Brown et al., 2004; Eusgeld and Kroger, 2008), models which incorporate systems theory and develop networks which adapt to their environment are considered to be the state-of-the-art (Eusgeld and Kroger., 2008; Xiao et al., 2008; Ouyang, 2014; Bevir, 2007).

For example, Dudenhoeffer et al. (2006) use a conventional graph theory concept to define an infrastructure system as a collection of nodes, links, and edges which represent the dynamic and complex nature of the system. The dynamic aspect of the system is demonstrated by the fact that the network can grow overtime (through increase in the number of nodes); it can evolve (through changing links between the nodes), or entail complexity (through non-linear effects of nodes on one another which also change the state of the nodes). Saidi et al. (2018) develop a similar multi-layered framework for the civil infrastructure system (see Figure 8) which shows different types of interdependencies between various physical infrastructure sectors, and the broader social, economic, and political environments. The framework also clearly identifies the type of relationship as physical, geographical, logical, or cyber. Such multi-layered networks offer a type of 'systems-of-systems' framework which model a range of interdependencies across different infrastructure sectors.

Figure 8: A systems-of-systems view with different dependency types

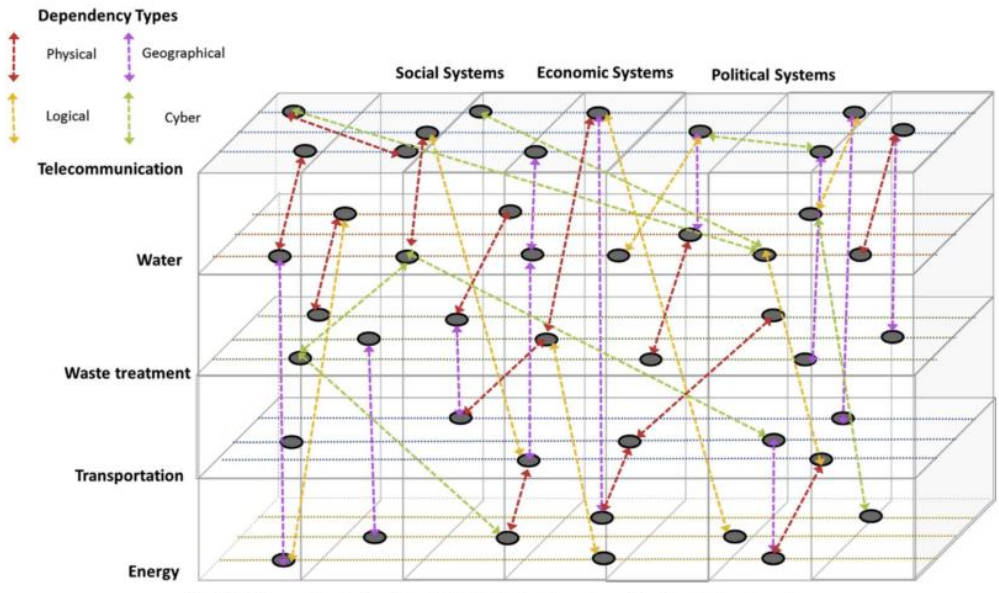
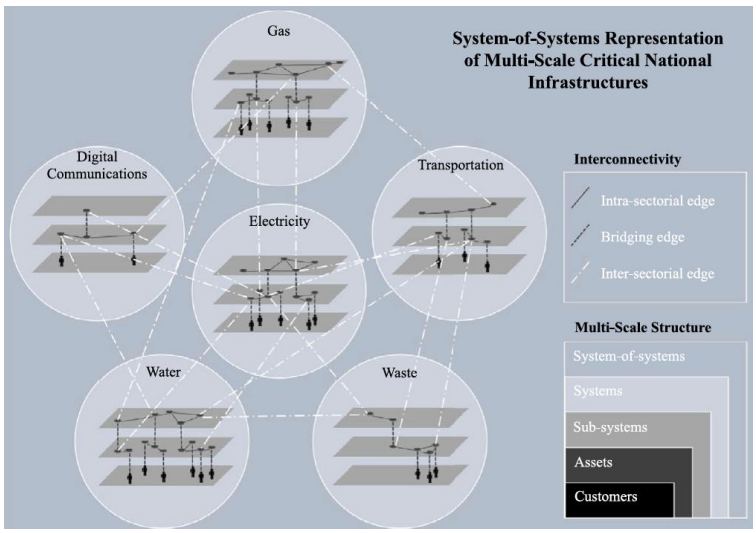


Fig. 1. Multilayer network of an integrated civil infrastructure system with different dependency type.

Source: Saidi et al. (2018)

The level of detail with which such relationships/interdependencies are specified varies, and primarily depends on the goal of the framework. For example, disruption analysis inherently involves detailed specification of interdependencies at the outset of the analysis whereas predicting long-term performance of infrastructure systems may not involve the same level of detail. Thacker et al. (2017), is an example of the former. The authors characterize critical national infrastructures as a system-of-system framework to perform a multi-scale disruption analysis. Their framework requires a detailed specification of the physical and geographic network interdependencies between sectors. The authors model each type of infrastructure such as water or electricity as a sub-system comprising of a group of nodes and edges with their specific flows (see Figure 9). They use this model to perform a multi-scale disruption analysis and draw predictions on how failures in any individual sub-systems can potentially lead to large disruptions.

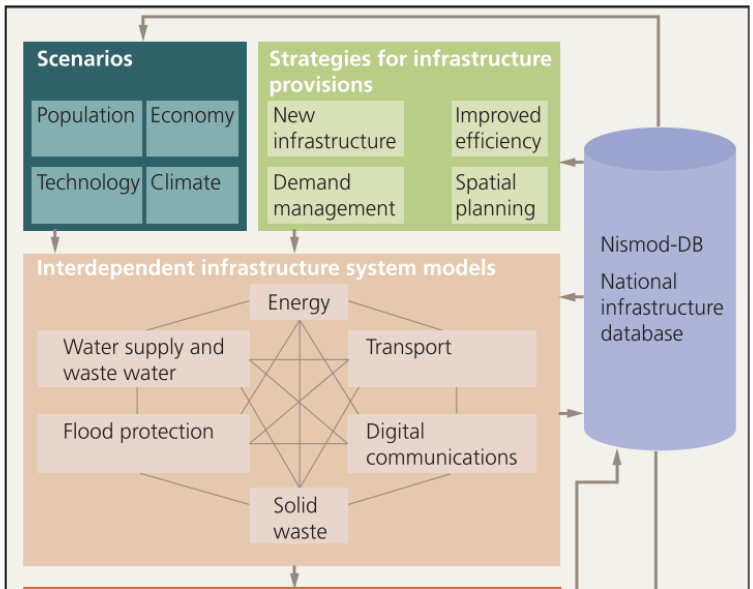
Figure 9: System-of-systems representation of six critical national infrastructures



Source: Thacker et al (2017)

On the other hand, Hall et al. (2017) develop a national infrastructure assessment framework with the aim to assist decision-makers in analyzing the long-term performance of interdependent infrastructure systems. In contract to Thacker et al. (2017), this requires less detailed infrastructure interdependency modelling and a greater focus on understanding the common underlying drivers for infrastructure demands across sectors. This framework deals with each infrastructure sector – energy, transport, digital communications, water supply, waste water, flood protection, and solid waste – in a consistent model and assesses exogenous socio-economic drivers which may impact on all sectors (e.g. population growth, the rise of integrated ICT systems changes the demand patterns for classical infrastructures). It focuses on explicitly specifying how one sector may place demands on other sectors, or how a sector-specific capacity installation (a waste to energy plant) may add capacity in another sector (to electricity production). The focus of this framework on the national, long-term, and capacity/demand perspective leads to a choice of a comparatively descriptive system, because a very detailed representation of the interdependencies would be overconfident, over-complex and consequently, unhelpful (Otto et al., 2016).

Figure 10: Modelling Future Performance



Source: Hall et al (2017)

Some macro-systems frameworks do not focus on specific physical interdependencies but rather focus on explaining how a specific infrastructure project is influenced by its users, external stakeholders, asset managers, operators, and political decision-makers. Such frameworks, which include humans, often draw on qualitative disciplines to explain interdependencies. For example, Masood et al. (2016) develop a conceptual framework with the aim of future-proofing (i.e. anticipating future changes and needs to prepare appropriately to minimise ecological impact) infrastructure with two dimensions: infrastructure resilience (resilience to unexpected events) and change management capability (capability to adapt to changing needs). Ottens et al. (2006) propose a high-level framework to characterize how technical elements in an infrastructure system may interact with human actors and social institutions to determine system performance.

The focus and scope of macro-systems approaches used in infrastructure systems also depends on how system boundaries are drawn. For example, many authors view infrastructure services along with their management as part of the infrastructure system. The waste sector is one such example which includes both physical as well as management elements such as manufacturing, transportation, urban growth, development, land use, and public health considerations. This highlights the complexity between the physical components of the system and its social and environmental spheres (Seadon, 2010).

4.3 Micro-systems Approaches

Compared to health and education, assessing the impact of an infrastructure investment or a specific policy after its implementation is less common and hence the literature on the subject is less widespread. This can be attributed to the nature of infrastructure - its long-lifetime and costly resources warrant investment into detailed modelling to simulate how different infrastructure investments will perform in the future exante, with lesser focus on estimating the impact of the investment once it has been made.

One exemption to this is the development literature, where the effectiveness of an infrastructure intervention is often dependent on the local population using it. In such cases, impact of infrastructure is defined as how the infrastructure construction, rehabilitation or maintenance has affected people's lives (Hansen et al., 2011). The focus of development agencies on results and value for money has led to an increase in impact evaluations to demonstrate the effectiveness of infrastructure development programmes (Hansen et al., 2011). A range of quantitative methods are employed such as experimental methods (where random assignment is possible), quasi-experimental methods (in large-n cases), computational general equilibrium models (in small-n cases), and cross-country regressions. There has also been a recent surge in evaluating infrastructure investments for environmental outcomes, for example carbon emissions. Law et al. (2017) for example use energy analysis, an environmental accounting system, to evaluate the direct and indirect energy inputs into these infrastructures to give an indication of sustainability outcomes. Such infrastructure evaluations are valuable to decision makers and urban planners who aim to improve standard design and implementation practices for infrastructure projects.

Similar to health and education, infrastructure systems research can also rely on evidence aggregation methods such as meta-analysis to identify the impact of specific types of green infrastructures. For example, Filazzola et al. (2019) conduct a meta -analysis to study whether green infrastructure is beneficial for biodiversity as compared to conventional infrastructure.

Another area where micro-systems approaches are used in infrastructure systems research is in designing infrastructures. These approaches tend to be grounded in decision-analysis methodologies, which at times also draw on qualitative techniques. For example, scenario modelling and robust decision-making methods use multiple views of the future to identify conditions under which a decision would fail to meet its objectives (Lempert et al. 2006; Lempert et al. 2013). Similarly, hybrid methodologies tend to integrate stakeholder input into how infrastructure systems are designed. We give details on formal scenario planning, robust decision-making, and hybrid methodologies below.

Formal scenario planning embraces the concept of multiple future views (Bradfield et al., 2005). Scenarios are often presented as narratives of descriptions of possible paths into the future and can be differentiated in to three classes. These include probable scenarios (what will happen); possible scenarios (what could happen), and preferred scenarios (what should happen). Such scenarios are typically produced in group exercises where three to four such possible paths are generated (Wilkinson and Eidinow, 2008). These are intended as a set to stimulate group thinking and help decision-makers evaluate those strategies that perform well across multiple futures (Lempert et al., 2009). While it can be difficult to capture a wide range of potential futures in a limited set of scenarios, scenario analysis is the least complex of these techniques and has been widely employed for policy review and in infrastructure assessments.

Robust decision-making is applied using computer simulation models to test strategies against a range of potential futures. This involves considering hundreds to millions of scenarios – enough that one matches the actual future (Lempert, 2003). Such an exploration of the future aids policy-makers in determining those strategies in which performance is relatively insensitive, in other words 'robust', to key uncertainties. For example, Kalra et al. (2015) defined a robust portfolio of water reservoirs in order to implement Lima's long-term water resource plan. Such an approach can also help to define pathways that allow for flexibility and adjustment of the strategy once new information becomes available and future developments become more predictable.

Hybrid methodologies integrate stakeholders throughout the decision-making process for infrastructure development, prior or post modelling. Prior to the modelling, stakeholders may be engaged in defining which infrastructure interventions to model, or which criteria for performance modelling to choose (e.g. determining those infrastructure investments with least cost, least environmental impact, etc.). Such stakeholder methodologies typically make use of a number of methods, including Delphi or participatory backcasting. Delphi methods seek agreement on future infrastructure trends from a wide range of experts (Gordon, 1964). Such experts respond to a list of questions, review each other's answers, and revise their views accordingly in an iterative fashion. Stakeholders may further be integrated to define which infrastructure assets to model (e.g. building a new power plant, small solar parks, etc.) through participatory backcasting in which a single normative vision of the future is developed and different pathways are developed to reach that vision (Touminen et al., 2014). Tuominen et al (2014) propose a new strategy for backcasting studies called *pluralistic backcasting*, in which multiple visions of the future are developed through a participatory and interdisciplinary

process that engages key stakeholders and users. Following this, policy packages that can potentially become pathways to these alternate visions are collaboratively developed with stakeholders. Post modelling, stakeholders can be integrated to encourage open discussion of trade-offs between different criteria, focusing on strategic, agreed-upon objectives rather than each stakeholder's personal cost and benefits.

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