Theory of Change Framework for Economic Evaluation Using Health System Models

Sakshi Mohan[1], Paul Revill[1], Martin Chalkley[1], Tim Colbourn[3], Tara D. Mangal[2], Margherita Molaro[2], Dominic Nkhoma[4], Bingling She[2], Simon Walker[1], Andrew N. Phillips[3], Timothy B. Hallett[2], and Mark Sculpher[1]

[1]Centre for Health Economics, University of York, York, UK
[2]MRC Centre for Global Infectious Disease Analysis, Jameel Institute, School of Public Health, Imperial College London, London, UK
[3]Institute for Global Health, University College London, London, UK
[4]Health Economics and Policy Unit, Kamuzu University of Health Sciences (KUHeS), Lilongwe, Malawi

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Abstract

All-disease health systems models (HSMs) represent the new frontier of economic evaluation to help guide sector-wide resource allocation, allowing for decision analysis in the context of interacting health system capacity constraints. Although there are frameworks for how health systems and their relationship with health outcomes may be characterised, there is a gap in the literature in providing a comprehensive list of health system components and a template for impact pathways from health system components to health outcomes to consider when designing, using and communicating HSMs for economic evaluation. This paper provides a conceptual framework to serve as a theoretical underpinning for the design and use of HSMs developed for economic evaluation. The framework builds upon previous literature as well as our experience developing the Thanzi La Onse (TLO) Model for Malawi.

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1 Introduction

Countries around the world face difficult choices as to the allocation of scarce healthcare resources to meet virtually infinite population healthcare needs. The choices made determine who receives healthcare, when and where this is received and, as a result, the health improvement that is generated. Although the objectives of healthcare policymakers can vary, a reasonable principal objective in most cases is to generate the greatest level of population health improvement from within the means available, often including equity concerns.

Health economic evaluations seek to guide such resource allocation choices. They can be defined as "the comparative analysis of alternative courses of action, in terms of both their costs and consequences" [1]. Since healthcare resources committed to one purpose consequentially become unavailable for other means, the assessment and consideration of health opportunity costs – which can be defined as the health gains that could be achieved from committing those resources to an alternative purpose – becomes critical. Economic evaluation aims to determine whether the health gains offered by an intervention, programme or some other budget allocation exceed or are equal to health opportunity costs, i.e. if they offer "value-for-money". Although the methods employed within economic evaluation have broad applicability, they have tended to be utilized to assess the value for money of new drugs or health technologies that are being considered for reimbursement in public healthcare systems. This might be because costs and effects of such interventions can be reliably estimated, for instance through randomized control trials, and opportunity costs can often be identified. Methods have also been expanded to evaluate public health interventions [2], investments in social determinants of health as well as investments into further research [3].

One area which notably lags behind is the application of economic evaluations to guide investments in systems-level policies and interventions, including health system strengthening [4]. A recent systematic review of economic evaluations of health system strengthening, for instance found "(no) studies evaluating economies of scope from single versus joint production, or estimating the cost- effectiveness of health systems strengthening interventions across the health system more broadly" [5]. One reason for this may be that government and health systems have not investing in this type of research. Another could be that evaluations of such policies raise a series of methods challenges, resulting from the fact that consequences of system-level policies often follow diverse, complex, and sometimes irreversible pathways, and call upon varied programme budgets, which make it challenging to pinpoint alternative budget use options. As a result of these methods challenges, analyses in this area have "often focused on estimating causal effects on short-term surrogate outcomes, (which) are of limited value for decision making as they fail to reflect the policy-relevant outcomes and disregard opportunity costs" [6].

All-disease health systems models (HSMs) represent the new frontier of economic evaluation to help guide sector-wide resource allocation, allowing for decision analysis in the context of interacting health system capacity constraints. Chang et al (2017) define the "field of 'health system modeling' as an area of research where dynamic mathematical models can be designed in order to describe, predict, and quantitatively capture the functioning of health systems" [7]. Borghi & Chalabi (2017) [8] discuss the potential uses of system dynamics models (SDMs) and agent-based models (ABMs), which are able to capture the complex non-linear associations between elements of a complex system, in providing a "computational experimental framework for optimising the performance of a health system prior to in vivo testing of pilot programmes... (and also to) inform the design of subsequent empirical evaluations".

Examples of such health systems models used to guide policy include the One Health tool and the Spectrum suite of tools developed by the Avenir Health group, and the Equitable impact sensitive tool (EQUIST) by UNICEF [9] to prioritise and cost national health sector strategies. However, the available tools lack the ability to assess the *value for money* of systems-level interventions in health.

In this paper, we provide a conceptual and methodological framework to design, use and communicate health systems models for the economic evaluation of health interventions at various stages in the 'disease/illness/care pathway' [10]. To guide the development of this framework, we relied upon the Thanzi La Onse (TLO) model. The TLO model is the first of-its-kind "detailed simulation model, rooted in country-specific data, that represents each step in the generation of health gains by service delivery in the healthcare system" through modelling the need for healthcare in a dynamic population, the effectiveness of care delivered and the healthcare resources available to deliver care [11]. By modelling the pathways and mechanisms of converting resources to health gains, it offers an opportunity to address the economic evaluation of system-level interventions. While the framework in this paper was developed with the TLO model in mind, the concepts generalise to similar model representations of healthcare systems which may be developed in the future. The framework described here draws upon existing literature to offer a more comprehensive view of the health system and the care pathway in a manner which is relevant to dynamic health systems models such as TLO developed with the objective of guiding health sector investments and policy design to achieve relevant targets of policymakers.

The first part of the paper develops a **conceptual framework** which seeks to provide a theoretical underpinning for the design of health systems models (HSMs) for economic evaluation and the framing of economic evaluation questions. The framework draws extensively from previous literature to provide a comprehensive picture of various elements of the health system along the pathway of care and the relationships between them. These include the policy and financing context, demand-side factors and supply-side factors influencing health service delivery and utilisation, and the target outcomes of health systems which are produced as a result. Economic evaluation inevitably presents a series of analytical choices which need to be made when defining, analysing and interpreting a resource allocation problem. The second part of this paper provides a **methods framework** for the use of an HSM for economic evaluation. We provide a description of analytical choices to be made and reported on when evaluating interventions using an HSM.

2 Conceptual Framework for the development of Health Systems Models (HSMs)

2.1 Review of previous contributions in the area

Many useful frameworks to conceptualise health systems have been developed since the early 2000s when the need to look at health sector investments beyond service delivery began to gain momentum. Theoretical frameworks have been put forward with three objectives –

1. Clarify definitions, i.e. to demystify the health system, its components, and their interrelationships; and to provide a definition of health systems strengthening.

2. Assist the health system planning process by incorporating systems thinking into planning through an acknowledgement of interlinkages between system components, dynamicity and feedbacks in

effect, and a recognition that any changes made within the health system cannot happen in isolation, i.e. they have repercussions across and beyond the sector.

3. Guide evaluation by providing structure to characterise "complex" interventions the impact of which is difficult to measure in terms of a single metric, as is possible in the case of simpler health services. Frameworks try to offer some conceptualisation of the pathways through which system interventions achieve measurable and comparable outcomes and therefore guide the definition of objectives, evaluation methods data collection and indicator identification.

The rapid review identified 13 relevant framework papers which can be grouped into four broad categories based on how they conceptualise the health system and its relationship with health production (See Table 1). Note that these categories are not mutually exclusive and were created to draw out the primary features of these frameworks. The review was restricted to studies which did the following - i. provided a visual or mathematical representation of the health system or system-level interventions, and ii. had the comparative evaluation of interventions or avenues of investments in the health sector as their central objective in defining the framework. Studies with the aim of 'describing the health system', 'health system benchmarking', or more generally, 'identifying and assessing the strengths and weaknesses of the health system' [12] were excluded from the review[1].

The first category of literature characterises the health system as a ***set of "non-hierarchical" building blocks***. These are general frameworks not linked to a specific evaluation methodology but were developed to encourage systems thinking when considering health sector interventions. The first and most influential among these is the WHO health systems building blocks framework published in 2007 [13]. This described the health system as consisting of six building blocks – i. service delivery, ii. health workforce, iii. information, iv. medical products, vaccines and technologies, v. financing, and vi. leadership and governance. This framework was then expanded to separate global health initiatives from country health systems [14], social determinants of health and societal partnerships (eg. with civil society groups) from health service delivery platforms [15], and further to differentiate between health system architecture (delivery platforms, services, workforce, population) from policy levers (such as financing and organisation) [4].

The second category views the health system as a ***determinant of the efficiency of health production or feasible coverage of services***. Four [16, 17, 18, 19] out of the six frameworks in this category adopt a simplified approach in theorising the health system in a way that is compatible with mathematical programming approaches for resource allocation decisions. All focus on service delivery platforms, defined as "logistically related service delivery channels that collectively make up the organisational components of the healthcare system, and mark the point of contact between service users and healthcare providers" [18]. Whereas Morton et al (2016) [16] see health systems investments as improving the production efficiency of the service delivery platform. Hauck et al (2019) [18] further consider investments increasing the underlying capacity of the platform or building a new platform altogether. And finally, Kirwin et al (2022) [19] tie these formulations of 'horizontal investments' in the health system together in a more generalised mathematical framework capturing imperfect divisibility of resources, value spillovers between interventions, and intertemporal decision-making. Ochalek et al (2018) [20], on the other hand, view the health system as a capacity constraint setting an upper limit on the coverage of services. This

[1] A detailed review covering health systems frameworks and assessment tools more comprehensively can be found in Chapter 2 of Papanicolas et al (2022) [12]

capacity can be expanded (or the 'constraint can be relaxed') through allocating resources towards HSS. None of these papers delve into the details of the various avenues of HSS. UNICEF's Equitable Impact Sensitive Tool (EQUIST) adapts the 1978 Tanahashi model to represent the health system as a set of demand, supply and quality factors determining the feasible effective coverage of interventions. The demand, supply and quality factors are measured in percentage terms for instance, the percentage of cases for whom the required medical consumables will be available on the supply side, the percentage of first Antenatal Care (ANC) visits which will convert to the requisite number of visits on the demand size, and, on the quality side, the percentage of pregnant women who had all ANC visits in a timely manner in accordance with focused ANC guidelines. The tool then allows analysts to put in assumptions on how they expect the effective coverage of interventions to change through investments in addressing these bottlenecks.

The third category places the patient/health-seeker at the centre of the health system and views the system as imposing a ***series of constraints on the 'disease/illness/care pathway'***. For instance, Vassal et al (2016) [10] view health system resources and context as a series of constraints applied to the pathway through which care is accessed by individuals arguing (similarly to Van Baal et al (2018) [17]) that even trials or decision analytic models assessing specific medical technologies should seek to capture the repercussions of the service across the system and that of the system on services. Similarly, De Silva et al (2014) [21] advocate for the use of a formal theory of change (ToC) characterisation for program evaluation tracking the pathway through resources, identification/diagnosis, treatment, long-term outcome to the ultimate impact.

Rather than defining health system interventions, the fourth category of frameworks simply emphasise the ***web of complex relationships*** which exist between components of the health system, which are not only linear but can be one of many types of relationships characteristic of complex adaptive systems [22, 23, 24]. All the three studies identified the linear 'input-output-outcome impact chain approach'[23] to health systems as inadequate to capture the 'web of complex relationships' [24] and the multi-directional and ongoing system interactions that follow from any health system intervention. Whereas Mcdonnel et al (2004) [22] and Paina & Peters (2012) [24] advocate for *mechanistic System Dynamic Models (SDMs)* to simulate the complexity of health system interactions within a large causal loop, De Savigny et al (2009) [23] highlight the importance of evaluation designs such as *plausibility design* and *adequacy design* focused on studying contexts and operational feasibility of interventions.

2.2 New Conceptual Framework for Health System Models (HSMs)

Figure 1 represents our proposed conceptual framework for HSMs. The rest of section 2.2 describes why we thought that a new framework for representing health systems was needed, how the framework was developed and how we propose for it to be used.

2.2.1 The need for a new framework

The health system frameworks highlighted in section 2.1 have been useful in expanding the general understanding of health systems and their interaction with the context, service delivery and health outcomes. The first category of frameworks provide a starting point for understanding the various components of the health system which should be considered when analysing resource allocation questions for the health sector. However, they did not delve into providing a template for a generalisable theory of

change linking these components. Without delving into the details of the different types of 'platforms' in the health system, the second category offers a useful simplification for the evaluation of horizontal and vertical investments but despite being less data and computationally intensive than dynamic modeling approaches, it requires a series of assumptions on the relationships (and spillovers) between horizontal investments and the efficiency or feasibility of service delivery which can be quite challenging to define mathematically. The third category addresses both these challenges by offering a clear impact pathway with the specification of health system components but it is centered around the evaluation of a single intervention which occurs within the context of the health system rather than capturing the complete health system and all its functions. The fourth category begins to delve into providing a framework for defining HSMs but falls short of providing a generalisable template for these.

As described in section 1 and noted in the literature [4, 8, 7], we envision health system models becoming an important evaluation tool for the health sector in the coming decades. In light of this, and given our experience with the development of the TLO model, we thought it was important to provide a generalised framework for the development of an HSM geared towards economic evaluation. The defining principles for the HSM framework we propose are as follows:

1. It is **comprehensive** in capturing the health system components discussed in the current literature and allows for the representation of the wide gamut of possible health system interventions, which have a direct or indirect effect on health.

2. It is **adaptable** to inter-disciplinary considerations and analyses, including epidemiology, economics, implementation science, and organisational behaviour.

3. It is conducive for the presentation of results through a **theory of change lens** so that the causal assumptions of any evaluations can be made clear. Setting out the pathway of impact clearly, following principles from theory of change, allows for a better understanding of model inputs to be changed to simulate the effect of a policy as well as spell out unintended/emergent consequences in a systematic manner. "In order to develop complex interventions which are more likely to be effective, sustainable and scalable, evaluators need to understand not just whether, but how and why an intervention has a particular effect, and which parts of a complex intervention have the greatest impact on outcomes." [21]

4. It is amenable to the **intervention design and planning process** through multi-stakeholder deliberation by providing a useful skeletal structure of interlinkages to consider. We found that the non-hierarchical building blocks structure can be difficult to navigate when trying to capture causal relationships of potential interventions. Further, our framework is conducive to determining contextual conditions necessary to achieve intended outcomes, estimate resource requirements and the system components which need to be involved in meeting the resource and contextual requirements.

5. It offers the **flexibility** of demonstrating the effects of various kinds of interventions within the same framework as well the joint effect of those interventions, if needed. Policymakers often need to consider multiple policies in conjunction with each other and not just in isolation. While the care pathway and theory of change frameworks [21] from previous literature are useful in offering a highly flexible and customisable way to capture interventions, they are not amenable to capturing diverse or combination interventions.

6. It is **adaptable to different health system contexts**. Although the framework we offer is most suited to primarily publicly funded health systems where the major resource allocation decisions are centrally coordinated, we believe that it can be suitably adapted for other types of health system.

7. It is **simple** to understand. HSMs are complicated and capturing the granular and comprehensive impact pathway of system level interventions can be challenging to comprehend. This framework aims to strike a balance between providing a comprehensive depiction of key elements of the impact pathway and being user-friendly and accessible.

2.2.2 How was the HSM conceptual framework developed?

The frameworks listed in Table 1 provided a useful starting point to characterise the health system components and impact pathways for our proposed framework. We augmented this with the health system performance assessment (HSPA) framework by Papanicolas et al (2022)[12] for further detail on the definition of sub-components within our framework. Finally, because HSPA framework from Papanicolas et al (2022) did not adequately cover social determinants of health and health care seeking, we explored other sources [25, 26] for insights on the links between these components and the health system.

To set boundaries on the components captured by our framework, we adopt the definition offered by WHO (2010) - "A health system consists of all the organizations, institutions, resources and people whose primary purpose is to improve health. This includes efforts to influence determinants of health as well as more direct health-improvement activities" [27]. Based on our experience with the TLO Model, we set out the impact pathway in a manner which we expect to be compatible with most HSM designs. In the language used by our framework, we envision HSMs to try to represent various components of the 'Health System' and 'Wider Context' and try to assess the value of 'Final outcomes' through quantifying 'Intermediate outcomes'. The framework is agnostic to the final goals of the health system which may include of population health improvement, social and financial protection, customer satisfaction, system resilience or responsiveness [27], or other wider goals [28].

2.2.3 How to to use the HSM Conceptual Framework

The main motivation behind the development of the conceptual framework for HSMs is to guide the design, use and communication of economic evaluations using HSMs. Prior to considering the structure and components of an HSM, the initial question to ask is whether a complex HSM is the appropriate method to evaluate the health system questions being asked and then what type of HSM is most suited to the questions - System Dynamics Model (SDM), Discrete-event simulation (DES), or Agent-based model (ABM). Guidance on these questions has previously been provided by the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) [29, 30]. We intend for the framework to be used at the following stages of HSM development and use, once these initial decisions on evaluation methodology have been made -

1. At the stage of **designing an HSM**, the framework can be used to make a decision on the components which the model will seek to capture, either in detail (mechanistically) or at a high level (non-mechanistically) [11]. In other words, the framework can help identify model inputs to be changed to simulate the effect of a policy as well as spell out unintended consequences in a

systematic manner. Figure 2 demonstrates the components of the framework which are captured by the TLO model.

2. When considering the **representation of interventions** within the context of the HSM, the framework can aid the development of the ToC. An intervention does not need to reside within a specific organisational component of the health system [23].

3. When **presenting results**, the framework offers a helpful template to demonstrate the impact pathway and the underlying contextual, methodological, and data assumptions applied. As noted by Weinstein et al (2003) [31], the purpose of a model is not to make unconditional claims about the consequences of interventions but to reveal the relationship between assumptions and outcomes.

3 Application of the framework: TLO Model Case Study

Figure 3 shows an example of how an analysis of the impact of investments in Supply Chain Strengthening may be represented using this framework.

4 Discussion

There has been a large and growing interest in health systems research over the past two decades, due to an increasing recognition of the importance of health systems in realising health benefits. Notable valuable contributions have been made to facilitate understanding of the impact of health systems on health outcomes but they have not ventured far into addressing how economic evaluation can be conducted in practice to guide health care investments. In this paper, we offer a conceptual and methodological framework to design, use and communicate health system models for the economic evaluation of interventions from a systems perspective. Drawing from previous literature, the framework offers greater clarity on the categorization of various types of health interventions and a template for a generalisable theory of change which can be used by analysts as at various stages of the development and use of an HSM. The proposed framework is not meant to replace previous health system frameworks presented in this paper that may be more appropriate for methodologies such as trial-based evaluation or mathematical programming. Further, the framework does not necessarily need to be used in a standalone way, but could be combined with other frameworks discussed in this paper, depending on the intervention being evaluated. However, it has been developed to be more suited to dynamic modelling methodologies (such as the TLO model), which we believe will become a commonly used tool in economic evaluations in the coming years. The importance of such health system modelling tools, covering all diseases, is likely to increase in low and middle income countries especially as the relative importance of donor funding, focusing on distinct disease programme, declines; as sustainability of investments and system resilience draws more attention due to decline in donor support and system-wide risks of various forms, as we have seen in the era of COVID-19; and as modelling skills in the field of health economics and computing capacity expands, with an accompanying desire for greater interdisciplinary research drawing upon inputs of varied experts.

HSMs offer large promise to better guide resource allocation in coming years, but their use will not come without challenges. They take significant amount of time and resources to build, large amount of data required to ensure fidelity to the context for intervention evaluation and they are computationally very

expensive, at least initially. Further, the causal links from health system interventions to health outcome are still difficult to capture within these models. Mechanistic models may need to be supported by inputs from other studies (such as econometric analyses, behavioural analyses, implementation science etc.) to understand the impact of high-level system interventions on surrogate outcomes, from which full effects can be propagated through the health system architecture and interactions, which can be reasonably captured within models. It is to be seen whether researcher skills to populate and run such models and the level of policymaker understanding to make full use of their capacity can be sustained to make their use in decision-making routine in future. Further thinking is needed to understand how economic evaluation principles can be extended to analyses using HSMs. This paper does not delve into these questions.

Over the next few years, the Thanzi La Onse model will be used to conduct a series of economic evaluations of potential health policies and interventions in order to help the Ministry of Health, Malawi use resources more efficiently to achieve the objectives set out in the Health Sector Strategic Plan III (2022-2030). We hope that the framework presented in this paper will help design and present these evaluations in a comprehensible and transparent manner to effectively guide decision-making.

Table 1: Comparison of conceptual frameworks for the evaluation of system-level interventions

Framework category	Reference	Characterisation of the health system/system-level interventions	Relevant evaluation methodology	Contributions of the framework
1. Health system as a set of "non-hierarchical" building blocks	WHO Health Systems Framework [32, 13]	Health system composed of six building blocks with a series of interrelationships – i. service delivery, ii. health workforce, iii. information, iv. medical products, vaccines and technologies, v. financing, and vi. leadership and governance	NA (Conceptual framework for systems thinking in the context of healthcare)	1. Recognised that vertical investments (direct expenses on service delivery) are only one component of the health system 2. Offered a way to categorize system-level interventions by "building block" 3. Provided a framework to identify interventions which require systems thinking based on joint magnitude of complexity and potential for system-wide effects
	The 'Control Knobs' Framework (Roberts et al, 2008) [33]	Framework focused on an action-oriented grouping of health system interventions - i. financing, ii. payment, iii. organisation, iv. regulation, v. Persuasion	[Pending]	
	Samb et al (2009) [14]	Conceptual framework of the interaction between global health initiatives and country health systems, consisting of the health system building blocks from WHO's framework	Unspecified	1. Drew attention to the impact of vertical Global Health Initiatives on country health systems 2. Placed "Health Service Delivery" at a separate level from the other five WHO framework-based building blocks providing some insight into the Theory of Change (ToC).

	Verguet et al (2019) [4]	Health system elements/architecture (delivery platforms, services, workforce, population) and policy levers (financing, payment, organization, regulation, persuasion) as two components of health systems	Health system modelling	Improved the WHO framework by distinguishing between two levels of health systems interventions (architecture, and policy levers), facilitating the mapping of interrelationships between these two groups of interventions
2. Health system interventions as a determinant of efficiency in health production or feasible coverage of service delivery	Morton et al (2016)[16]	• HSS as an investment to leverage the economies of scope that exist within any health system, in the form of delivery platforms shared across interventions, whose nature and effectiveness determine cost structures within the system. • HSS are investments that do not contribute to health directly but are instead complementary to existing delivery systems. • HSS helps bridge the gap between lab-based efficacy of interventions and real-life effectiveness, which is diluted as a result of weal health systems.	Mathematical programming/Constrained optimisation	1. Facilitated the application of a straightforward method to prioritize across horizontal and vertical investments across programs over a single period 2. Reduced the data and computational requirements for mathematical programming by aggregating all kinds of HSS into one variable (y_j) influencing the efficiency of healthcare production (by an econometrically estimated dilution factor, γ) 3. Implied that in the complete absence of "horizontal" investments, "vertical" investments would be ineffective.

	Van Baal et al (2018) [17]	Health system as a a set of input constraints (going beyond just a general budget constraint free to be used in any way) which changes the interpretation (and potentially value) of the ICER of an intervention and consequently the decision rule for resource allocation.	Mathematical programming/Constrained optimisation	1. Offered a clear decision rule for resource allocation in the presence of multiple input constraints 2. Highlighted that multiple shadow prices exist when there is more than one resource constraint 3. Demonstrated how conventional ICERs can be adjusted to account for the displacement of resources as a result of implementing an intervention in the presence of input constraints

	Ochalek et al (2018) [20]	Health system as a group of demand and supply constraints acting together to place independent limits on the feasible level of coverage of each health intervention	League table with budget constraint/Constrained optimisation	1. Like Hauck et al (2019) [18], offered a computationally inexpensive way to characterise how policymakers might think of resource allocation towards HSS relative to disease control programmes from a fixed budget constraint 2. Offered a way to characterise constraints at the level of each health service, allowing a departure from the theoretical understanding that the system would allocate its resources sequentially towards cost-effective services ("optimal allocation") until their coverage is maximised. 3. added service specific demand constraints, which cannot be addressed simply by "expanding platform capacity", to the understanding of system constraints.

	Hauck et al (2019) [18]	Three types of HSS investments are discussed • "Investments in platform efficiency": Investments affecting the efficiency in health production by currently employed health system inputs (following Morton et al (2016)[16]) • "Investments in platform capacity": Investments expanding the health system inputs available for health production • "Investments in new platforms" - Investments into new platforms which were not previously available and can support a number of existing or new interventions	Mathematical programming/Constrained optimisation	1. Expanded the definition of 'horizontal investment' beyond efficiency improvements [16] and capacity expansion [17] to the establishment of new platforms 2. Captured interdependence between interventions not only in terms of shared efficiency benefits from HSS but also shared (limited) resources to deliver the interventions 3. Offered an explicit decision rule for resource allocation based on the relative cost effectiveness of HSS and vertical investments

	Equitable Impact Sensitive Tool (EQUIST) [9]	Health system as a set of demand, supply and quality constraints limiting the percentage of the population which ”effectively” covered by health interventions	Bottleneck analysis combined with the Lives Saved Tool (LiST)	1. Offered a practical data-based tool for countries to identify and compare healthcare priorities in terms of populations, diseases, interventions, and specific combinations of HSS strategies 2. Allowed countries to identify the most pressing system constraints causing 'bottlenecks' in service delivery 3. Brought attention to income-based health distribution equity as a goal of the health system and how that can be incorporated into decision-making

	Kirwin et al (2022)[19]	Offered the same three characterisations of horizontal investments as previous mathematical constrained optimisation frameworks [16, 17, 18] but allowed for more generalisable representation capturing imperfect divisibility of resources, value spillovers between interventions, and intertemporal decision-making.	Mathematical programming/Constrained optimisation	Expanded the representation of the resource allocation problem previously demonstrated [16, 17, 18] as follows - 1. Offered a representation of interventions which affect more than one of the three plaform functions previously proposed (capacity, efficiency, new platform) 2. Allowed for multiple budget constraints and perfect divisibility by moving from linear to integer programming 3. Removed the assumption of constant returns to scale and 4. Allowed value spillovers between horizontal and vertical investments 5. Allowed intertemporal optimisation through the inclusion of multiple time periods and discounting

3. Health system as a series of constraints on the pathway to care	Vassall et al (2016) [10]	Demand and supply constraints on the care pathway from onset of symptoms to treatment taken (specific to a medical technology)	Trials/Implementation research/Decision analytic economic models with system constraint considerations	1. Offered a paradigm shift in the way in which medical technologies are defined within economic evaluations, by demonstrating the value of moving economic evaluations from assessing the "hypothetical" cost-effectiveness of medical technologies in a perfect, unconstrained environment to assessing "actual" benefits and costs of technologies in the context of demand and supply constraints. 2. Pushed evaluations of medical technologies to consider a wide range of "proximal" and "distal" system forces and to adopt the perspective of a health -seeker rather than health provider 3. Offered a clear description of the ToC 4. Was amenable to a multi-stakeholder consideration of constraints
	(De Silva et al., 2014)		Impact evaluation/Randomised control Trials	1. Offered a clear description of the ToC ("how", "why" and "which parts of" an intervention create the effect) 2. Was amenable to a multi-stakeholder consideration of constraints

4. Health system as a series of complex relationships	Mcdonnell et al (2004)	Health system (health workers, health expenditure, infrastructure) interact with each other and are part of a bigger causal loop which encompasses the economy (eg. GDP, disposable income)	System Dynamic (SD) modelling	1. Expanded the health system perspective to include economic consequences 2. Offered a detailed representation of causal pathways between health system components, non-health system components and offers the flexibility of breaking down the relationships and causal pathways within each component, through a description of sub-models defining each component (eg. doctor resources, GDP)
	De Savigny & Adam (2009) [**?**]	A move from linear input-output-outcome impact chain to systems approach which sees interventions as a system itself (a pattern of behaviour rather than an event), places emphasis on the context, and views causality as an ongoing process rather than a one-time event (such as in the case of feedback loops)	Plausibility design; Adequacy design	1. Advocated for evaluation designs emphasising operational feasibility and generalisability through a focus on documenting contexts 2. Offered a way to bring out negative or unintended consequences through collective brainstorming 3. Improved the potential for successful implementation by engaging ”street-level” policy implementers at the design stage of interventions

	Paina & Peters (2012) [24]	Rather than defining health system interventions directly, the paper discusses how scaling up the coverage of health services requires consideration of the web of complex relationships between components of the health system ("healthcare providers, patients, officials, and other stakeholders") and the broader context ("communities of practice, neighbourhoods, social networks"), rather than a linear analysis of additional resources required for service delivery expansion	Complex adaptive systems; System Dynamic modelling (SD); Agent-based modelling (ABM)	Drew attention to the fact that even health service interventions involve system wide implications

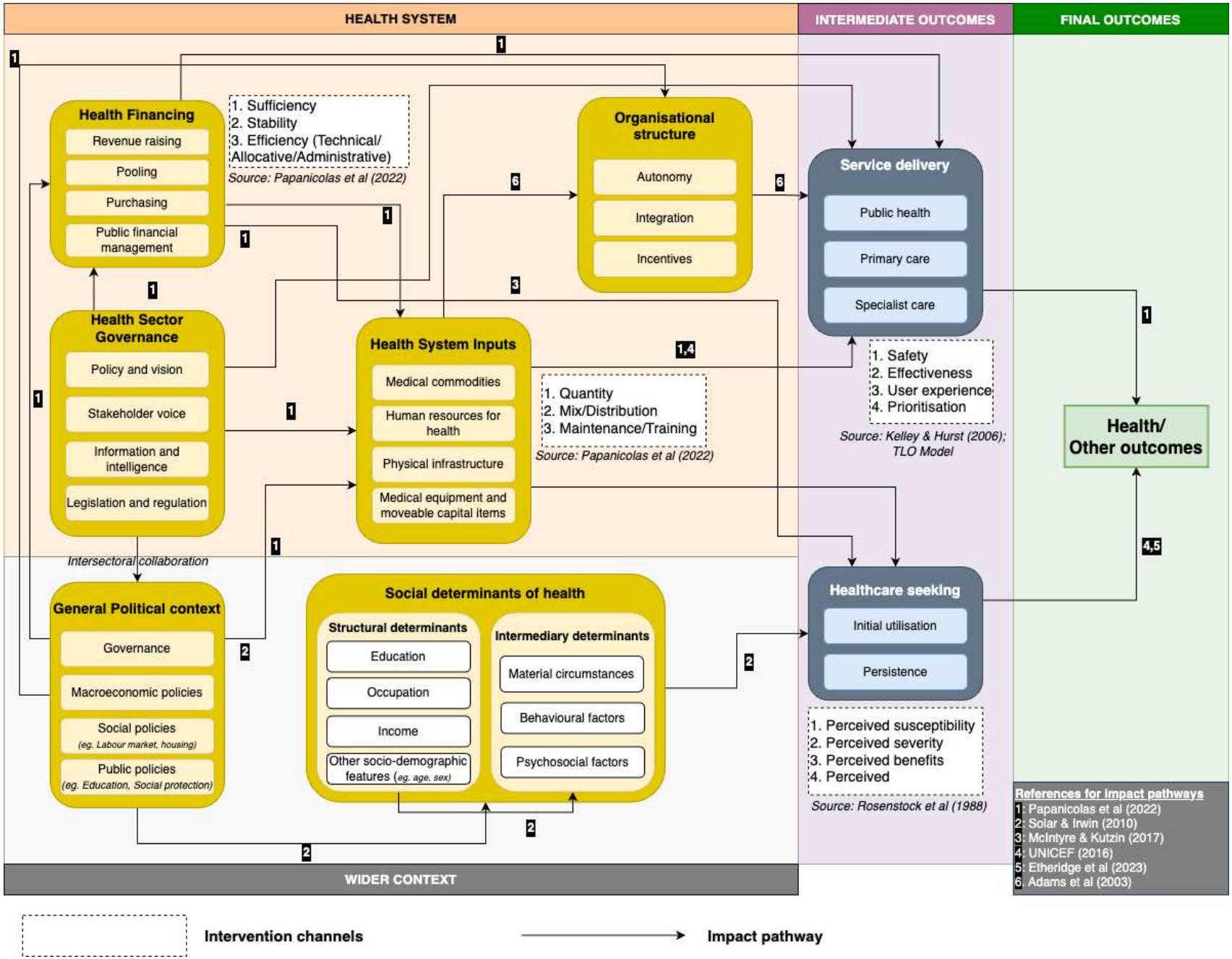

Figure 1: *Conceptual Framework for HSM*

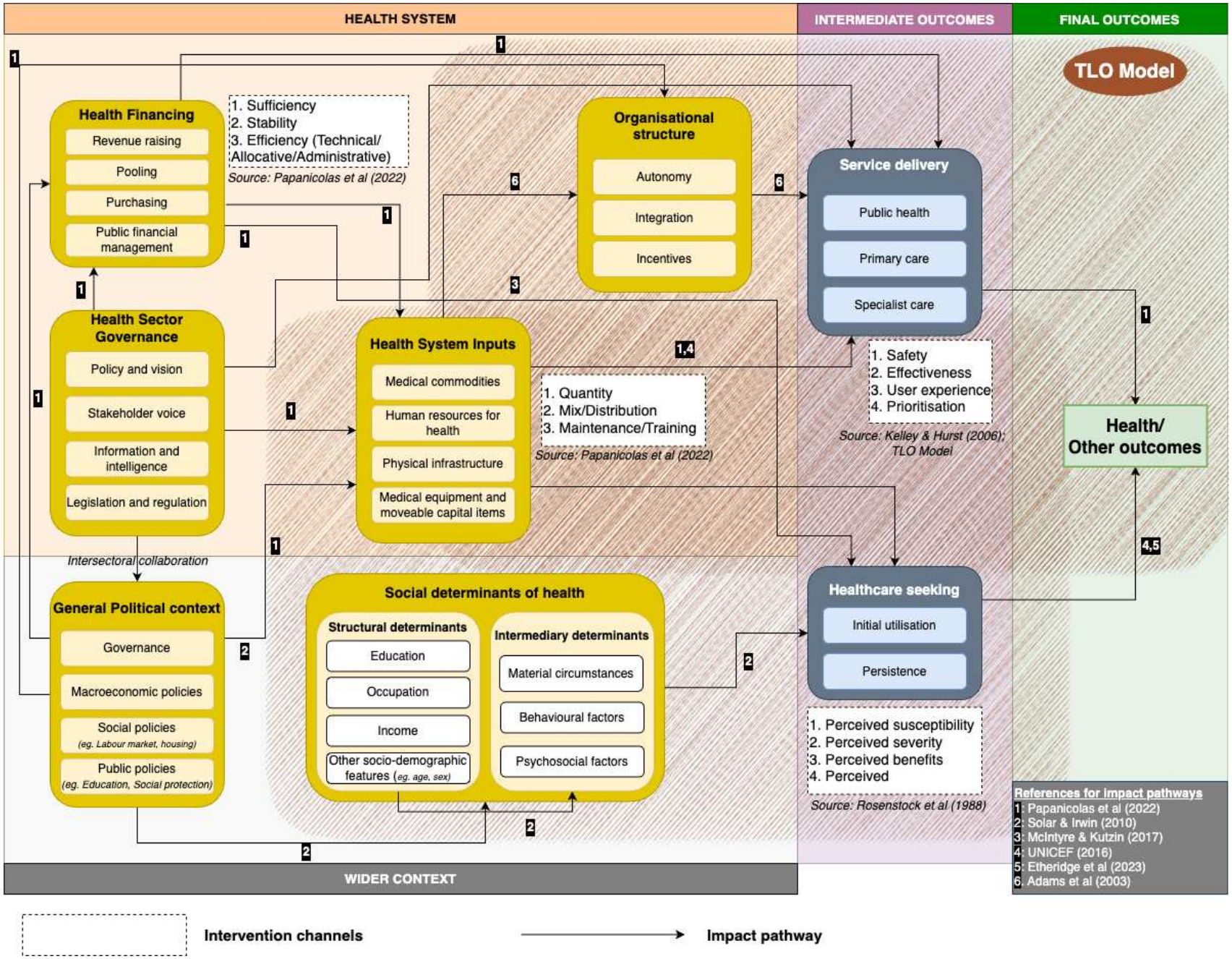

Figure 2: *TLO Model placed within the Conceptual Framework for HSM*

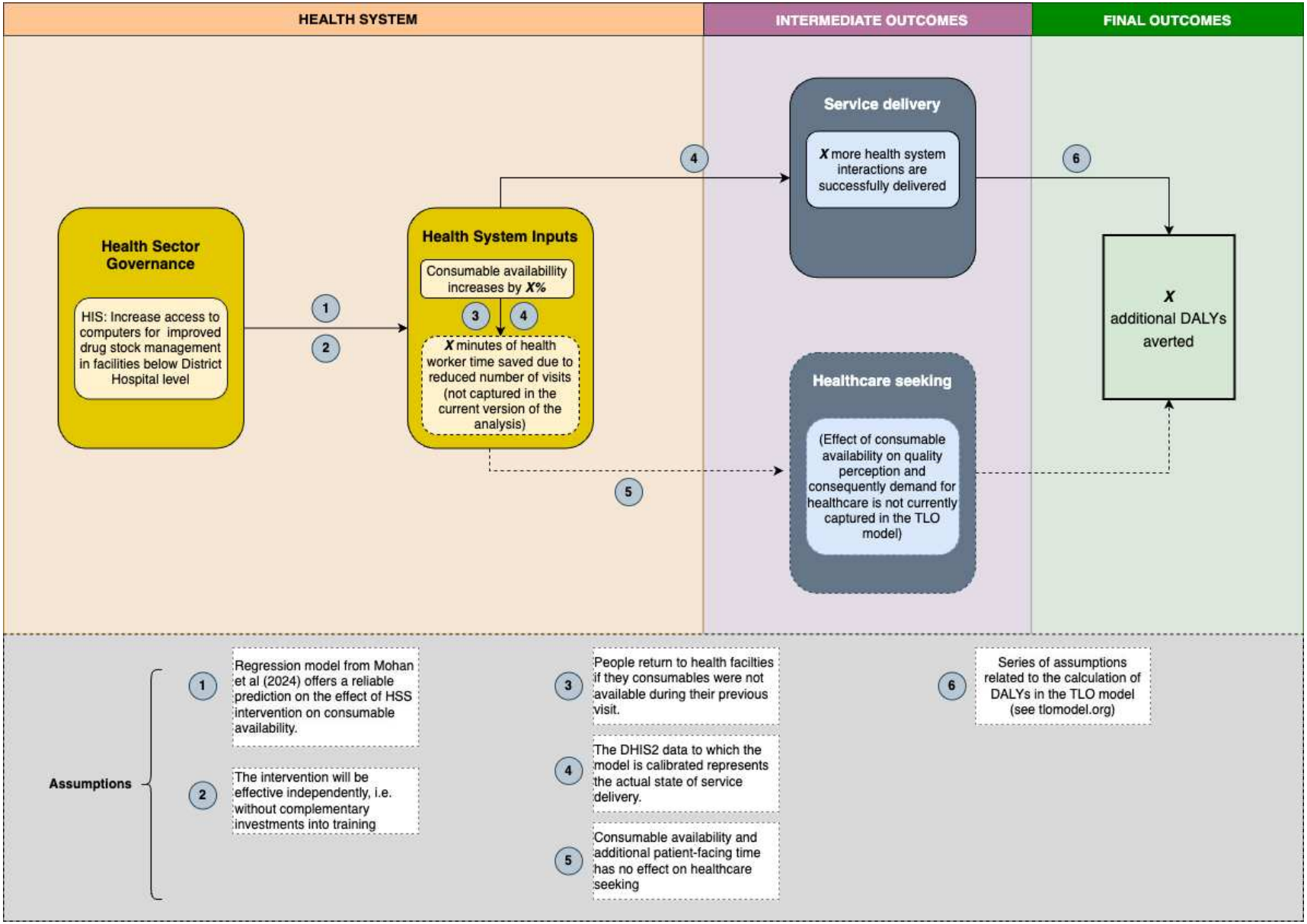

Figure 3: *Representation of a system-level intervention to improve consumable availability within the HSM framework*

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