Health Policy and Planning, 2026, 41(4), 584–598
https://doi.org/10.1093/heapol/czag017
Published: 10 February 2026
Original article

OXFORD

Understanding the role of 'software' in health system capacity for non-communicable disease response: hypertension care in rural Coastal Kenya

Robinson Oyando [1]*, Nancy Kagwanja [2], Brahima A. Diallo [3], Syreen Hassan[4], Jainaba Badjie[3], Ruth Lucinde[5], Noni Mumba[2], Samson Muchina Kinyanjui[2,6,7,8], Pablo Perel[9], Anthony Etyang[5], Edwine Barasa[1,6], Ellen Nolte[4†], Benjamin Tsofa[2†]; on behalf of the IHCoR-Africa Collaborators

[1]Health Economics Research Unit, KEMRI Wellcome Trust Research Programme, PO BOX 43640-00100, Nairobi, Kenya
[2]Health Systems and Research Ethics Department, KEMRI-Wellcome Trust Research Programme, PO BOX 230-80108, Kilifi, Kenya
[3]Nutrition and Planetary Health, MRC Unit the Gambia at LSHTM, PO BOX 273, Banjul, The Gambia
[4]Department of Health Service Research and Policy, London School of Hygiene and Tropical Medicine Faculty of Public Health and Policy, Keppel Street, London, WC1E 7HT, United Kingdom
[5]Department of Epidemiology and Demography, KEMRI-Wellcome Trust Research Program, PO BOX 230-80108, Kilifi, Kenya
[6]Center for Tropical Medicine and Global Health, Nuffield Department of Medicine, University of Oxford, Old Road Campus, Oxford, OX3 7LF, United Kingdom
[7]Department of Biochemistry, Pwani University, PO BOX 195-80108, Kilifi, Kenya
[8]Institute of Healthcare Management, Strathmore University, PO BOX 59857-00200, City Square, Nairobi, Kenya
[9]Department of Non-Communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, Keppel Street, London, WC1E 7HT, United Kingdom
†Joint senior authors.
*Corresponding author. Health Economics Research Unit, KEMRI Wellcome Trust Research Programme, PO BOX 43640-00100, Nairobi, Kenya. E-mail: ROyando@kemri-wellcome.org

Abstract

Research on health system capacity to manage non-communicable diseases (NCDs) has largely focused on 'system hardware' such as infrastructure, workforce, and commodities. However, this overlooks the critical role of 'system software' elements, such as relationships, norms, and power, and the complex adaptive nature of health systems. This study aimed to explore how health system hardware and software elements interact to shape the capacity of the health system to deliver hypertension care in Kilifi County in the coastal region of Kenya. We conducted a cross-sectional qualitative study and collected data using document reviews ($n = 13$) and in-depth interviews with purposively selected front-line health workers (FLHWs) at five health facilities and health managers at county and national levels ($n = 37$). We applied a framework approach to data analysis, utilizing complex adaptive systems (CAS) theory as our analytic framework. Complex interactions of system hardware and software elements constrained the provision of hypertension care. Frequent medicines stockouts (hardware) stemmed from budgetary gaps, procurement delays, regulatory restrictions, and weak quantification practices (software). To mitigate medicines shortages, facilities employed adaptive responses such as inter-facility borrowing and sourcing from alternative suppliers (software). Access and continuity of care were enabled by organizational norms like dedicated hypertension clinic days (software) but undermined by inadequate consultation rooms, staff shortages (hardware) and limited training and support supervision (software). FLHWs' ideas to improve medication adherence were undermined by staff shortages (hardware) and inadequate support from facility managers (software), weakening service delivery. The application of CAS theory unpacked the hitherto underexplored aspects of health system capacity. System 'software' plays a central role in shaping health system capacity for hypertension care. Therefore, strengthening health system capacity for NCDs requires coordinated investment in both system hardware and software elements. Importantly, system strengthening interventions should consider the CAS nature of health systems to foster conditions for productive emergence.

Keywords health systems, health financing, non-communicable diseases, complex adaptive systems

Accepted: 24 January 2026

Key messages

- Existing assessments of health system capacity to address the rising burden of non-communicable diseases (NCDs) have predominantly focused on hardware elements like infrastructure, supplies, and equipment. This research applies complex adaptive systems (CAS) theory to offer a more holistic assessment by examining how hardware and software elements of the health system interact in shaping health system capacity for primary care management of hypertension in Kenya.
- Hardware constraints such as inadequate funding, medicine stockouts, and inadequate infrastructure were exacerbated by software factors including under prioritization of NCDs, procurement delays, policy restrictions on stocking certain antihypertensives at lower-level facilities, and weak communication and coordination between suppliers and facilities. Adaptive responses such as interfacility borrowing and informal rationing emerged to mitigate gaps in medicine availability, highlighting nonlinear and emergent behaviours characteristic of CAS.
- To address gaps in hypertension care, policymakers should act across both hardware and software dimensions such as streamlining funding disbursements from pre-paid sources to reduce procurement disruptions (software); and instituting increases in health taxes (hardware and software). Additional mechanisms that target system software include health workers' training and targeted guideline dissemination to enhance knowledge about hypertension and its management.
- The study demonstrates that effective NCD management requires targeted investments in both hardware and software elements of the health system to foster conditions for productive emergence rather than isolated fixes.

Background

Non-communicable diseases (NCDs) such as cardiovascular diseases are the leading causes of morbidity and mortality globally, accounting for 74% (41 million) of deaths worldwide, with over 85% of premature deaths occurring in low- and middle-income countries (LMICs) (World Health Organization 2025). The growing NCD burden in LMICs is placing unprecedented pressure on health systems, many of which were historically oriented towards the control of infectious diseases (Savedoff et al. 2025). There is an increasing focus on understanding health system capacity and readiness to deliver NCD services (Gupta et al. 2020, Kabir et al. 2022, Ahmed et al. 2024b). However, a critical appraisal of the literature reveals important limitations in how health system capacity for NCDs is conceptualized and assessed (ibid). There is currently no consensus on how to define health system capacity; we conceptualized it as encompassing three interacting dimensions: 'system hardware' (e.g. financing, workforce, equipment); 'tangible software' (e.g. knowledge, skills, processes); and 'intangible software' (e.g. relationships, norms, communication), which collectively enable a health system to meet population health needs (Aragón and Giles Macedo 2010, Elloker et al. 2012, Meyer et al. 2012, Ali et al. 2013).

Empirical studies of health system capacity for NCDs have predominantly employed 'hardware-centric' frameworks (Gupta et al. 2020, Kabir et al. 2022), often adapted from the World Health Organization's Service Availability and Readiness Assessment and similar tools (World Health Organization 2013). Facility-based studies across sub-Saharan Africa using these frameworks have consistently documented significant deficits in the availability of trained health workers, basic diagnostic tools, essential medications, and service delivery infrastructure, particularly at the primary healthcare (PHC) level (Mutale et al. 2018, Bovet et al. 2021, Ammoun et al. 2022, Adejumo et al. 2023).

These studies provide important insights into infrastructural constraints but offer only a partial, static view that fails to capture health systems' dynamic, interdependent, and adaptive nature (Adam and de Savigny 2012). Some studies (Tesema et al. 2021, Chham et al. 2023) have examined software elements, such as availability of treatment guidelines, referral systems, leadership, and governance in the management of NCDs, finding these to be suboptimal in Cambodia and Ethiopia. However, there remains a significant lack of understanding of how system hardware and software elements interact to enable, or indeed undermine, a health system's capacity to respond to NCDs.

Recent health policy and systems research advocates recognizing health systems as complex adaptive systems (CAS), incorporating CAS principles to better capture their interactive dynamics and emergent behaviours underpinning service delivery (Ali et al. 2013, Rusoja et al. 2018, Burger and Gilson 2025). CAS theory conceptualizes health systems as comprising multiple interconnected agents whose behaviours are interdependent, adaptive, and influenced by evolving contextual conditions (Plsek and Greenhalgh 2001, Begun et al. 2003, Gilson 2012).

Yet few empirical studies have applied CAS frameworks to NCD capacity assessments. There is thus a need to reorient health system capacity assessments through the lens of complexity. Such an approach would move beyond static inventories of structural resources towards a more nuanced understanding of how systems function, adapt, and respond to the challenges of NCD care. By integrating both hardware and software dimensions, and focusing on their dynamic interactions, such an approach generates actionable insights for strengthening health system capacity in a sustainable and context-sensitive manner. This study addresses this conceptual and empirical gap by applying a CAS framework to assess health system capacity for delivering primary care for NCDs in a rural county in Coastal Kenya, focusing on hypertension—a prevalent condition that exemplifies the demands of long-term chronic care within resource-constrained settings.

Methods

This research was embedded within the Improving Hypertension Control in Rural Sub-Saharan Africa (IHCoR-Africa) project, which aimed to co-design and assess a community-based model for improving hypertension care in rural Kilifi, Kenya, and Kiang West, The Gambia (Perkins et al. 2023, Diallo et al. 2024). This paper's findings are specific to the Kenyan context.

Study design

We conducted a cross-sectional qualitative case study and collected data using document reviews, in-depth interviews (IDIs) with

frontline health workers (FLHWs) and decision-makers at facility, sub-national and national levels. Interview topic guides were informed by the study's objective and guided by the conceptual framework.

Study setting

Kenya has a devolved governance structure comprising a national government and 47 semi-autonomous county governments (Government of Kenya 2010). The national government handles policy, regulation, and the management of national referral hospitals (30% of health functions) while county governments oversee the delivery of health services in respective counties (70% of health functions) (Ministry of Health 2014, AFIDEP 2023). Counties are funded through national transfers, own-source revenue and donor support (Ministry of Health 2024b). Counties exercise autonomy in allocating health budgets based on local priorities and strategic plans (Ministry of Health 2024b). Health services are delivered through four tiers: community (Tier 1), dispensaries and health centres—hereafter referred to as PHC facilities (Tier 2), sub-county and county hospitals (Tier 3), and national referral hospitals (Tier 4) (Ministry of Health 2014). Public facilities account for about 45% of service provision, while the remaining share is provided by private for-profit, and not-for-profit actors (Moturi et al. 2022). Our study was conducted in Kilifi County, located along Kenya's coast. The local economy is primarily driven by subsistence agriculture, fishing, and tourism (Scott et al. 2012). The area also bears a high burden of NCDs (Etyang et al. 2014) (Supplementary File S1).

Participant recruitment

Interview participants were purposively selected based on their role in hypertension or NCD service delivery and their managerial/support role in overall service delivery at county and national levels. Respondents included MoH officials ($n = 4$), county and sub-county health managers ($n = 12$), facility managers ($n = 3$), FLHWs ($n = 14$) (e.g. physicians, pharmacists, clinicians, and nurses), and NCD stakeholders ($n = 4$). A total of 37 participants were interviewed (Table 1). Recruitment of FLHWs took place at purposively selected health facilities (dispensaries $n = 2$, health centres $n = 2$, and a hospital $n = 1$). Sub-county/county-level respondents were recruited from their workstations, whereas national level respondents were recruited via email and phone calls. All participants were briefed about the study and gave a written informed consent to participate in the study at a time and place convenient for them.

Data collection and document review was stopped upon reaching data saturation, defined as the point at which no new significant data were identified.

Data collection

Data were collected over 6 months between June 2023 and December 2023. Data collection was conducted by two experienced qualitative researchers.

Document review

To explore strategies for managing and financing NCDs in Kenya's health system, we conducted a document review using the READ approach (Dalglish et al. 2020). This structured method of document analysis involves four steps: (i) Read—familiarizing with the documents and their context; (ii) Extract—systematically capturing relevant data; (iii) Analyse—interpreting the data; and (iv) Distil—synthesizing findings into key themes. Documents were obtained from the Ministry of Health website and general internet searches, covering 2014–2023, and included policy guidelines, NCD policy documents, and hypertension treatment guidelines ($n = 13$) (Table 2).

Table 1 Number of IDI participants.

Participant category	*N*
National level	4
NCD stakeholders	4
County and sub-county health officials	12
Facility managers	3
Frontline health workers	14
Total	**37**

In-depth interviews

Interviews were digitally recorded, with supplementary notes taken during each interview. IDIs were conducted either in person at the respective health facilities and department of health offices where respondents were recruited or virtually via Zoom (for national level respondents). Interviews lasted between 45 and 60 minutes.

Conceptual framework

This study drew on a conceptual framework of organizational capacity proposed by Elloker et al. (2012), which builds upon the foundational work of Aragón and Giles Macedo (2010), who conceptualize organizational capacity as a multidimensional construct comprising tangible and intangible elements. According to Elloker et al. (2012), healthcare organizations can be understood as systems constituted by two interrelated dimensions: *hardware* and *software* components (Fig. 1). The hardware includes structural and physical assets such as infrastructure, medical technologies, human and financial resources. The software encompasses two domains: (i) *tangible software*, which refers to formal systems including managerial procedures, knowledge and skills and (ii) *intangible software*, which comprises elements such as values, norms, power, and relationships that influence organizational behaviour. Our categorization of health system hardware and software elements was also informed by and aligns to previous studies that have used the same framework (Mwamba et al. 2018, McLennan et al. 2023).

Whereas the Elloker et al. framework provides a useful heuristic for categorizing the constituent elements of health systems, it is limited in its ability to elucidate the interactions and emergent behaviours that arise from the interplay among these components. To address this gap, the study integrated complex adaptive systems (CAS) theory (see Box 1), a strand of complexity science increasingly used in health systems research (Begun et al. 2003, Barasa et al. 2017, Greenhalgh and Papoutsi 2018, Hodiamont et al. 2019, Sturmberg and Bircher

Table 2 Documents included in the review.

Document type	Publishing organization	Year of publication	Title
Treatment guideline	Ministry of Health	2024	Kenya National Guidelines for the Management of Cardiovascular Diseases
Treatment guideline	Ministry of Health	2018	Kenya National Guidelines for Cardiovascular Diseases Management
Treatment guideline	Ministry of Health and Healthy Heart Africa	2015	Protocol for the identification and management of hypertension in adults in primary care
Policy document	Ministry of Health	2021	National Strategic Plan for The Prevention & Control of NCDs 2021/22 - 2025/26
Policy document	Ministry of Health	2023	Kenya Essential Medicines List
Policy document	Ministry of Health	2020	Kenya Universal Health Coverage Policy 2020–2030
Policy document	Ministry of Health	2014	The Kenya Essential Package for Health (2014–2018)
Policy document	Ministry of Health	2014	Kenya Health Policy 2014–2030
Policy document	Ministry of Health	2014	Kenya Health Sector Referral Strategy (2014–2018)
Policy document	Ministry of Health	2020	Kenya Community Health Policy 2020–2030
Policy document	Government of Kenya	2023	Facilities Improvement Financing Act 14 of 2023
Policy document	Government of Kenya	2023	Primary Health Care Act No. 13 of 2023.
Health Sector Report	County Government of Kilifi	2023	Kilifi County Health Sector Review Task Force

NCDs, non-communicable diseases.

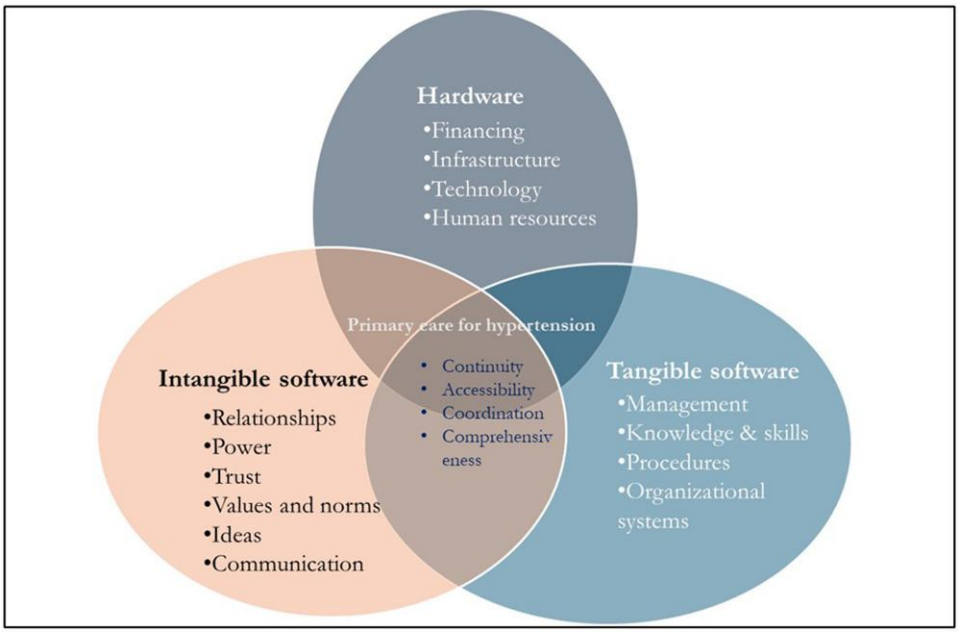

Figure 1 Study conceptual framework (adapted from Elloker et al. 2012).

2019, Asefa et al. 2020). CAS theory, although applied *post hoc* during data analysis, provides a lens to examine not only individual system components but also the nonlinear, emergent, and self-organizing behaviours that arise from their interactions (Zimmerman and Glouberman 2004, Greenhalgh and Papoutsi 2018). This perspective departs from linear, reductionist models by emphasizing the interdependence and adaptability of agents operating within complex environments.

Taken together, the integration of the Elloker et al. (2012) framework with CAS theory facilitates a more nuanced understanding of health system capacity-one that considers not only the presence of organizational components but also the dynamic, recursive, and often unpredictable ways in which these elements interact to shape health system performance. This dual-framework approach is particularly relevant for examining the delivery of hypertension care, a prevalent NCD condition characterized by multifactorial

Box 1 Key properties of complex adaptive systems.

Core to CAS theory are four properties widely recognized by complexity theorists (Marion and Bacon 1999, Begun et al. 2003). First, self-organization and emergence denote the capacity of agents within the system to respond autonomously and collectively to environmental stimuli, often resulting in novel patterns, structures, or practices that are not easily attributable to any single component (Lindberg et al. 2008, Zimmerman and Glouberman 2004). Such emergent properties reflect the non-additive nature of CAS, where the behaviour of the whole system cannot be reduced to the sum of its parts.

Second, nonlinearity implies that outcomes are not proportionally related to inputs; small interventions may yield disproportionately large effects-or none at all-depending on the timing, context, and configuration of the system (Begun et al. 2003). This characteristic underlies the unpredictability and path dependence inherent in complex systems. Third, CAS operate at the edge of chaos, a metaphor describing systems that exist in a critical zone between stability and disorder. This zone allows for both the flexibility needed for innovation and the structure necessary for sustained functioning (Marion 1999, Marion and Bacon 1999). Fourth, CAS exhibit robustness and resilience, enabling them to maintain functionality amid shocks or disturbances. This resilience is partly explained by the system's coupling patterns, or the degrees of interdependence among system elements. In *tightly coupled* systems, changes in one unit produce significant ripple effects across others, whereas *loosely coupled* systems allow for more isolated, contained responses (Marion 1999, Weick 1976). These coupling dynamics enhance organizational adaptability by permitting both coordinated action and localized innovation.

influences, chronicity, and the need for sustained system responsiveness.

Data analysis

All transcripts were cross-checked against the original audio recordings to ensure transcription accuracy. Documents selected for review together with verified transcripts were then imported into NVivo 12 (QSR International) for coding. A framework approach, informed by Pope et al. (2000), was employed to guide the analytical process. RO led the analysis, with iterative input and validation from all co-authors to ensure analytical depth and reflexivity. The framework approach was selected for its utility in generating policy-relevant insights and pragmatic recommendations. Coded data were organized into thematic matrices and critically interrogated within and across categories to identify salient patterns, conceptual linkages, and explanatory relationships (Pope et al. 2000). Interpretation involved mapping identified themes onto theoretical constructs and assessing their implications for health policy and practice. RO developed a causal loop model in Vensim to visualize interactions influencing health system capacity for hypertension care, which was subsequently reviewed and validated by all authors. Analytical rigour and trustworthiness were enhanced through multiple strategies: (i) use of theory; methodological triangulation; providing an audit trail—a detailed description of methods and analysis steps, and member checking (Gilson 2012). Member checking was conducted through a policy dialogue held in in Kilifi between 11–12th August 2025, involving FLHWs, sub-national and national health officials as well as cardiometabolic and health policy and systems researchers across multiple institutions. The feedback obtained guided the identification of areas requiring further in-depth analysis.

Results

We identified several factors influencing the health system's capacity to manage hypertension, encompassing hardware, tangible software, and intangible software elements (Fig. 2). These components interacted in complex ways that either constrained or enabled comprehensive, continuous, accessible, and coordinated hypertension care. Figure 2 illustrates these interactions through causal loops, showing how reinforcing and balancing feedback processes reflect key CAS dynamics discussed in the sections that follow.

Funding and financing of NCDs

Under-prioritization of NCDs

Several participants noted that, unlike relatively well-funded infectious disease programmes, NCDs were under-prioritized, with limited government and donor investment. This intangible software gap [under-prioritization of NCDs] undermined the capacity of the health system to provide hypertension care.

Budget constraints

Although the budgetary allocation to the health sector had more than doubled between 2013/14 and 2020/21 (from Ksh 1.3 billion (21% of total county budget) to Ksh 4.2 billion (29%) (County Government of Kilifi 2023), county-level decision makers shared that in every planning and budgeting cycle, they always faced difficult decisions in choosing which items to prioritize and allocate the limited budgetary resources.

> From my experience, one of the challenges is the funding. You know the health sector in the county takes a big chunk of the funds. Yet, you find that we still don't get 100% of our budgetary requests.—CMoH003

A national level respondent echoed similar sentiments of budgetary constraints by noting that *there is a ninety-five per cent financing gap* [NMoH 001] for the current NCDs strategic plan, a fact that was corroborated by the document review that indicated a 94% funding gap (Ministry of Health 2021).

To bridge the NCD financing gap [hardware], some participants proposed domestic resource mobilization through higher excise taxes on tobacco, alcohol, and sugary drinks. However, they noted that that power (intangible software) resided with the legislators to enact such a policy move and that such

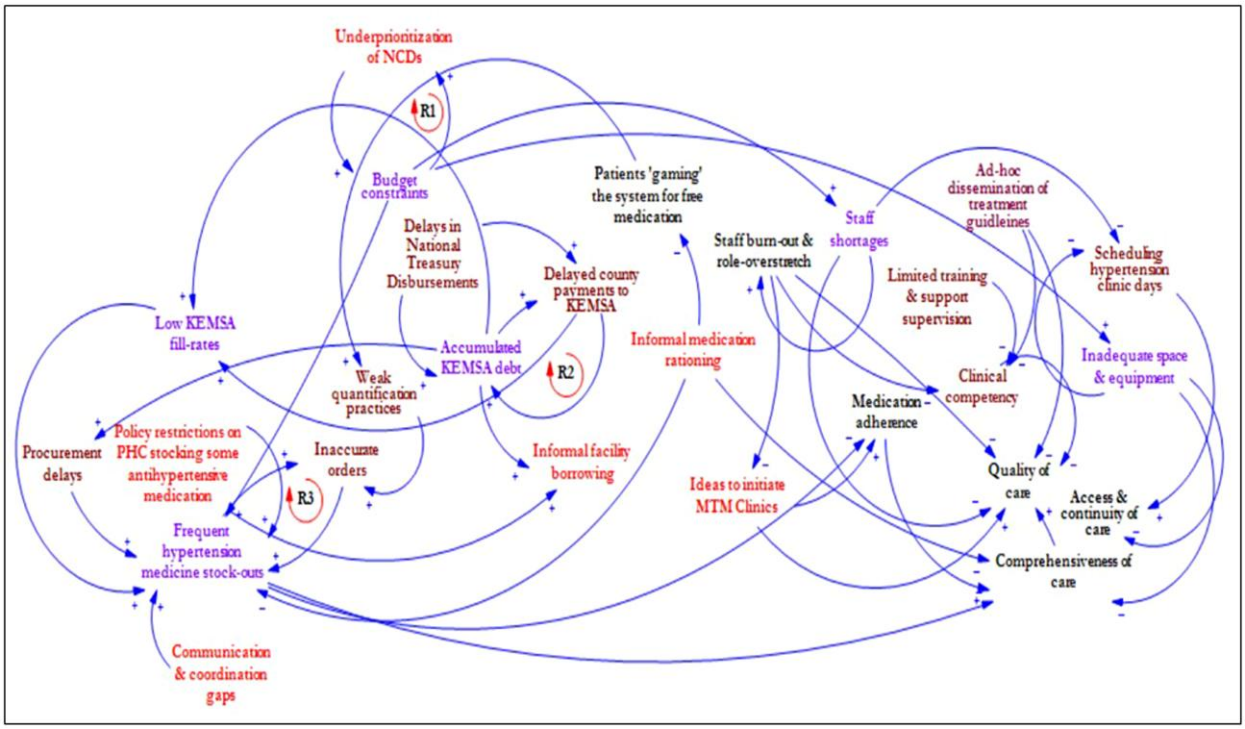

Figure 2 Causal loop diagram of factors influencing health system capacity for primary care management of hypertension.

measures would have limited impact unless the raised revenues were earmarked for NCD interventions.

> When they [members of parliament] make noise for this or that tax to be increased, including raising taxes on the things that we consider NCD risk factors, where does the money go? If we cannot plough back that money into the health sector, specifically for NCD care and management, we're missing the point.—NMoH001

Health facility financing sources and mechanisms

Financing sources were a key hardware factor influencing the capacity of health facilities at different levels of care to deliver NCD services. Under the free PHC policy adopted in 2013 (Ministry of Health 2020) and retained in the Primary Health Care Act of 2023 (Government of Kenya 2023b), PHC facilities relied mainly on three funding streams. First, the county government budgetary allocations direct investment in employing FLHWs, purchasing commodities from Kenya Medical Supplies Agency (KEMSA), a state-run corporation mandated to procure and distribute pharmaceutical and non-pharmaceutical commodities to public health facilities in Kenya. Second, PHC facilities received *Linda Mama* [free maternity programme] and capitation reimbursements from the now-defunct National Health Insurance Fund (NHIF). Third, these facilities obtained funds through Danish International Development Agency (DANIDA) conditional grants to support their operation and maintenance (Kairu et al. 2021, County Government of Kilifi 2023). A facility manager confirmed these sources as essential for sustaining service delivery.

> This facility does not charge; it is a Level 3 [health centre], and we are not supposed to charge clients. The facility depends on the Linda Mama…that is the main source of finance for this facility. And some DANIDA funds, which come once in a while.—Facility Manager, Health Facility 2

Despite these financing sources, PHC facilities still faced significant financial constraints because NHIF reimbursements were both unpredictable and the capitation amounts were deemed inadequate to meet the service delivery costs. Also, the DANIDA grant was in the process of being phased out, with the attendant effect of further shrinking their resource envelope [hardware gap].

> The financing of a Level 2 or a Level 3 facility is not as strong…they just rely on the NHIF capitation and the Linda Mama. But even then, the reimbursements from NHIF are not timely, and so they are not reliable.—CMoH004

By contrast, the policy allowed level 4 and 5 health facilities [secondary hospitals] (in addition to the three funding mechanisms at PHC facilities) to charge user fees and through the Facilities Improvement Financing Act of 2023 (Government of Kenya 2023a), to retain and utilize the revenue from user fees [tangible software capacity]. Of note, the disparity in financing arrangements between facility levels was perceived by some respondents as a potential driver of pervasive revenue maximization incentive where resources were preferentially allocated to hospitals that generated revenue through user fees.

> As I had earlier said, counties see these medicines as a form of revenue generation. This disincentivises them from pushing them to lower-level facilities where patients will not pay for them.—National NCD Stakeholder 001

A participant noted that some patients who could not afford medication learned to 'game' the system by attending their follow-up appointments for specialist review at hospitals but obtained their medication refills at PHC facilities where medicines were offered for free (Fig. 2).

> In levels 2 and 3, drugs are free. So, people have known how to circumvent the system. They come to KCH [Kilifi County Hospital], Dr. YY gives them a prescription, but then they will have to buy it. So, they go to Kiwandani [a Level 2 facility] with their prescription for refills.—CMoH 001

The differences in how health facilities at different levels were financed had mixed effects on patients and providers. From the patient perspective, it enabled access to free medication from PHC facilities. In contrast, from the provider perspective, it was unexpected and unpredictable behaviour (CAS feature), as it had negative effects characterized by erratic medication quantification due to inconsistencies in facility commodity consumption data (more details on Section 3.2.2).

Furthermore, in the context of a largely rural and poor population, participants reported that people living with hypertension could not afford to purchase medication elsewhere when supplies were out-of-stock and could not undertake diagnostic/monitoring tests that were unavailable at PHC facilities. These hardware gaps undermined continuity and comprehensiveness of care.

> People in this community are still financially down. So, patients are not able to go to the referral hospital for the tests. So, we treat and pray to God... they rarely go due to finances.—Facility Manager, Health Facility 2

Health products and technologies for hypertension care

The unavailability of health products and technologies (HPTs), including antihypertensive medication across various levels of care, especially at PHC facilities, was another critical hardware capacity gap that undermined the health system's capacity to provide comprehensive primary care for hypertension. We present the reasons for the prevalent stock-outs in the subsections that follow.

Procurement challenges for HPTs

Delays in payments to KEMSA

Delays in the disbursement of the national equitable share funds to counties by the National Treasury was a key factor in influencing commodity procurement in the county. This tangible software gap resulted in counties delaying payments to KEMSA. As a result, the entire procurement chain from the national to county level was interrupted as KEMSA could not source HPTs from their international suppliers in time to have enough stock for the entire country.

> If the National Treasury doesn't give county monies, counties can't pay KEMSA, so KEMSA also can't kind of procure from wherever they are procuring.—CMoH 002

Accumulated KEMSA debts

The accumulation of debts to KEMSA had a direct impact on medicine availability in health facilities. New commodity orders could not be placed until previous invoices were cleared. This not only complicated the commodity ordering process (which was theoretically intended to occur quarterly) but also led to stockouts that extended for months and depleted the 1-month buffer stocks.

> We are supposed to order quarterly, but if we owe KEMSA, we can't order. Even if the drugs are needed, the system won't honour the request.—CMoH 001

Communication and coordination challenges

Respondents highlighted challenges in communication and coordination (intangible software) between the county and KEMSA which meant that counties were not aware which commodities in their order were available at KEMSA stores until a delivery was made.

> So, you wait for KEMSA to bring, and you discover they do not have this, then you start raising another order.—CMoH 001

Communication and coordination gaps between KEMSA and counties persisted despite the existence of the Logistics Management Information System meant to guide ordering. Stock shortages at KEMSA often occurred when many counties placed large orders simultaneously after settling debts, quickly depleting KEMSA supplies.

County and health facility adaptations to adress HPT challenges

The county's good relationship and credit score with KEMSA, evidenced by a good credit rating, allowed it to receive commodities on credit while awaiting Treasury disbursements. This arrangement was formalized through commitment letters approved by KEMSA's senior management (tangible software).

> Normally, there are those commitment letters, and we involve the CEO, and he will look at it together with the Finance Director, and if it's a workable arrangement, we allow.—NMoH Official 002

Hospital revenues from user fees partly cushioned them from commodity shortages, enabling direct procurement from alternative suppliers. In contrast, PHC facilities relied on informal borrowing and redistribution, a short-term solution that was unsustainable as it widened inequalities between better-resourced hospitals and lower-level facilities.

> We do redistribution and borrowing... Like yesterday at XX [Level 3], they didn't have anti-hypertensive commodities, so they went to ZZ [sub-county hospital], and I was there, and we issued them.—SCMoH 001

These formal and informal relationships (intangible software) among actors in the health system facilitated efforts to overcome challenges in commodity procurement within the county.

Medication quantification challenges

Weaknesses in the medication quantification processes (tangible software) reflected a capacity gap. Due to the absence of a robust

information system (hardware), facilities lacked patient-level medication regimen data, resulting in frequent over- or under-ordering and consequently leading to expiries or stock-outs. As mentioned earlier, due to patients' limited capacity to pay, some would attend their clinic appointments at hospitals but take their medication refills at PHC facilities where they did not pay any user fees. Since the ordering of medication was based on facility consumption, this led to over- or under-quantification of medication at different levels of care.

> *They* [health facilities] *can't quantify because they don't know their clients…* - CMoH 006

> In fact, there are still some stores somewhere that have a lot of hypertension drugs that have expired because facilities would pull indiscriminately and hope that the clients show up and when they don't show up, they end up expiring.—CMoH 001

Pharmacy staff rationed anti-hypertensive medication (intangible software) by giving patients only part of their medication, especially those with quarterly clinic appointments. The pharmacy staff justified this behaviour due to the unpredictable and delayed KEMSA order deliveries.

> You can imagine, if I give everybody the three-month dose, I might give my ten patients, and then these other twenty remain without... So, I would rather make sure that everybody at least gets small quantities.—FLHW 001, Health Facility 4

The inability to accurately forecast commodity needs stemmed from non-linear patterns in patient attendance and fragmented data systems. These issues reflect emergent unpredictability and information asymmetry in complex systems.

Poor fill rates

KEMSA's fill rates (proportion of commodities supplied versus orders made) were perceived to have declined to below 50%, with essential medicines for NCDs often unavailable. Facilities depended on back orders (i.e. placing a new order after the initial one was unfulfilled), but these remained unmet for months, prolonging commodity gaps. As a result, there were significant disruptions in service delivery when the county realized, several months into placing an order, that more than half of the commodities were unavailable.

> *Like in the last order, the fill rate was 45% they didn't even have hypertension drugs…* - CMoH 001

> You might find the commodity was not even supplied in the first order, then the back order was done, but it was not supplied again...It can even be a whole year.—FLHW 001, Health Facility 3

To help mitigate shortages, KEMSA shared lists of alternative suppliers, but these vendors charged higher prices, hesitated to supply indebted counties, and had limited capacity for last-mile delivery (i.e. logistical ability to deliver commodities to health facilities in remote and marginalized areas).

Policy limitations on stocking certain anti-hypertensives in PHC facilities

PHC facilities faced restrictions on ordering specific anti-hypertensives drug classes due to policy and standard order form limitations (tangible software) (Ministry of Health 2023, Ministry of Health 2024a). As a result, the county relied on informal redistribution of HPTs across health facilities. This created inconsistency in patient care and limited comprehensiveness of care at PHC facilities.

> You know, some of these drugs are sent to the facilities by level. That's a challenge. When you look at the essential drug lists for a dispensary and health centre, some of these commodities that are required to treat or to manage these clients are not there in the standard order form for level two, level three.—CMoH 006

To cope with chronic stock-outs, some hypertension patients at a PHC facility pooled funds to buy medicines through the facility. However, the initiative lacked a guiding framework, and staff hesitated to coordinate purchases for fear of contravening the user fee policy.

Service delivery infrastructure for NCD care

Space constraints and congestion at facilities

Respondents from across PHC facilities reported lack of clinic space for hypertension service delivery. NCD clinics at PHC facilities often operated from outpatient consultation rooms shared with other patients, leading to crowding and limited privacy.

> There is no way even the patient can talk private things to the doctor... the support staff is here, the patient is there, and I, as the doctor, I'm here... There is not enough space for examination.—FLHW 002, Health Facility 3

Although some PHC facilities were willing to allocate more clinic days for NCD care, limited consultation space (hardware) compromised access to care, while overwhelming both staff and infrastructure. In contrast, hospitals responded to the high patient workload and the need for adequate consultation time by transitioning from conducting weekly to daily hypertension clinics. They designated specific FLHWs to manage these clinics and ensured a manageable number of patients were scheduled each day. This shift was feasible in hospitals due to the availability of consultation rooms that could be dedicated to daily clinic operations.

> We decided to group [hypertension patients] on various days so that we see them in [manageable groups] and we counsel them better.—FLHW 002, Health Facility 4

Space limitations at PHC facilities exemplify system constraints that restrict adaptability and self-organization. The lack of designated NCD spaces reflects a misalignment between infrastructure and evolving service needs, reinforcing fragmentation in care.

Equipment for supporting NCD service delivery

While basic equipment like blood pressure (BP) machines was reportedly present in many PHC facilities, their availability was

inconsistent, with significant maintenance, supply, and functional gaps undermining routine service delivery. Advanced diagnostic tools such as electrocardiograms remained confined to hospitals (Ministry of Health 2024a), reinforcing a tiered system of diagnostic access. Furthermore, although equipment existed, actual usability was compromised by lack of batteries, damaged parts, and supply delays. Procurement mechanisms were misaligned with local facility needs, as equipment budgeting processes was centralized and unresponsive. The equipment challenges were exacerbated by reliance on donor-driven contributions and donations, that were temporary or unevenly distributed across different levels of care. To cope with the equipment challenges one of the dispensaries leveraged an existing good relationship with a community member [intangible software] to borrow his BP machine during clinic days. These practices, while resourceful, highlight systemic fragility and the burden of improvisation on providers.

Human resources for NCDs service delivery

Workforce shortages and role overstretch

Many facilities were severely understaffed, especially PHC facilities (County Government of Kilifi 2023). Participants reported that sometimes a single clinician was responsible for all outpatient services, maternity, and NCD services such as hypertension care. To cope with staffing gaps, one PHC facility relied on a retired nurse to run the hypertension clinic. Whilst this ensured continuity of care, it resulted in burnout, poor quality of care, and missed care, such as vital sign checks or patient education. Similarly, some facilities relied on support staff such as community health promoters to help triage patients. Clinical roles were often delegated to support staff without standardized protocols or training. While this extended service reach, it also introduced inconsistency and risk.

> It's one clinician. Do you think it will be possible for you to screen clients? So, we won't provide quality services to the patient.—FLHW 002, Health Facility 3

These coping strategies reflect a classic CAS response: self-organization to meet staffing shortages. However, without sufficient tangible software (guidelines, supervision, referral protocols), this adaptation becomes unstable and prone to errors.

Communication and collaboration between FLHWs

At one facility, the pharmacist-in-charge and a colleague established a medication therapeutic management (MTM) clinic to support hypertension patients struggling with adherence. Effective collaboration and open communication with physicians (intangible software) enabled patient identification and enrolment. However, staff shortages, high pharmacy turnover (hardware), and limited facility management support (tangible software) hindered the clinic's operations and long-term sustainability.

> We stopped seeing patients every day because of staff moving away. Like the person who we started it [MTM clinic] with left... It's not as vibrant as it once was because of staffing issues.—FLHW 001, Health Facility 4

Training, dissemination of treatment guidelines, and support-supervision

Respondents reported infrequent training updates on NCDs, with most providers relying on clinical training, on-the-job learning, or *ad hoc* sessions from implementing partners to refresh their knowledge of hypertension management (tangible software gap). Systematic investment in NCD-specific competencies for FLHWs, particularly at PHC level, was limited. Consequently, facilities varied in their interpretation and application of hypertension guidelines, which were often unavailable. Participants emphasized the urgent need for structured hypertension training to enhance quality of care.

> Most of us have not been trained... I still rely on my knowledge from the Kenya Medical Training College [basic training college] *in Mombasa*.—FLHW 002, Health Facility 3

> Whoever gets something new, they share. Because the guidelines might be outdated... so people just follow what someone like Dr. YY brings back.—FLHW 002, Health Facility 4

Across all care levels, participants noted that cardiovascular disease guidelines were rarely disseminated beyond occasional physical copies. In the year preceding data collection, no NCD-related supportive supervision had occurred from sub-county, county, or national officials. This lack of systematic guideline dissemination and supervision contributed to variability in hypertension care quality.

Discussion

This study explored how hardware and software components interact to shape the health system's capacity to deliver hypertension care in rural coastal Kenya. Applying the Elloker et al. (2012) framework and CAS theory (Begun et al. 2003), our findings reveal a mixed hardware-software interaction that either enabled or constrained the health system capacity for hypertension care. On the one hand, our findings illuminated behaviours that reflected self-organization and emergent adaptation as agents within the health system adapted strategies to ensure uninterrupted commodity supply in the health system despite funding delays. For example, health workers bypassed formal procurement processes to keep services running. However, this informal flexibility can introduce instability and inequity, especially when resources are scarce and borrowing becomes competitive. In addition, this finding illustrates how tight feedback loops (e.g. between budget cycles, payment delays, and KEMSA fill rates) generate vulnerability and lag in the supply chain.

On the other hand, structural deficits (hardware) and institutional processes (software) interacted in dynamic and often constraining ways to undermine health system capacity for hypertension. For instance, frequent stock-outs of antihypertensive medicines were not merely a result of resource constraints but also stemmed from procurement delays, weak quantification practices and policy restrictions. Similar findings have been reported in Peru where unavailability of anti-hypertensive medicines was mainly driven by inefficiencies in the distribution system and medication quantification challenges, leading to overstocking and expiries in higher-level facilities and lack in PHC facilities (Williams et al. 2024). Moreover, our findings reveal that while hardware deficits —such as funding flow delays, inadequate financing, infrastructure,

and workforce—are significant; it is the interplay with software elements that critically determines system capacity.

In our findings, several of the adaptive strategies appeared to reflect unsustainable organizational behaviours—an occurrence referred to in CAS literature as 'maladapted emergence' (Marion and Bacon 1999). For instance, adaptive responses like interfacility borrowing of medication and informal rationing of medicines illustrate how frontline actors self-organize to maintain service continuity, reflecting the system's complex adaptive nature. Kagwanja et al. (2020) in their study that aimed to examine the challenges experienced by the health system at a sub-national level in Kenya reported a similar finding where health managers responded to a wide range of everyday stressors such as resource scarcity by borrowing drugs across facilities. Besides, the medication stocking policy requirement, while well-intentioned, represents a maladaptive simplification in system governance—an attempt to streamline ordering that fails to accommodate the dynamic evolution of service needs. It also reflects path dependence, where past assumptions about facility capability inhibit local responsiveness. Therefore, our findings affirm the central research question: health system capacity for NCDs, cannot be adequately understood through a hardware-centric lens alone. Instead, capacity emerges from dynamic interactions between hardware and software system elements, shaped by contextual constraints and adaptive behaviours.

Our study's findings align with and extend existing literature on health system capacity for NCDs in LMICs. Previous assessments, such as those by (Ammoun et al. 2022) and (Adejumo et al. 2023), have documented infrastructural and resource constraints in primary care settings. Furthermore, similar to findings documented in Tanzania (Peck et al. 2014) and Nigeria (Orji et al. 2021); our findings suggested critical gaps in training of FLHWs to manage NCDs like hypertension as well as *ad hoc* dissemination of cardiovascular treatment guidelines. Whilst these studies provide important evidence on priority policy intervention areas to inform health system response to the rapidly growing NCDs burden, we argue that static frameworks adapted by these studies overlook the adaptive and relational dimensions of health systems. Our findings confirm these infrastructural gaps but go further to illustrate how software elements—such as relationships, norms, and communication practices—mediate the effects of hardware deficits. The informal task-shifting practices among support staff reported in our study reflect the kind of emergent behaviours described in complexity-informed health systems research (Barasa et al. 2017, Asefa et al. 2020). Moreover, the study findings corroborate insights from Gilson et al. (2017), Sheikh et al. (2011), and Burger and Gilson (2025), who emphasize the importance of software in shaping health system performance.

Our study found that while some gains have been made in embedding hypertension care at select higher-level facilities, for instance, through establishing daily hypertension clinics in response to increasing demand for services, significant disparities remain, particularly across lower tier (PHC) facilities. Similar findings have been reported from previous health system capacity assessment studies conducted in other sub-Saharan African countries such as Ethiopia (Tesema et al. 2024), Ghana (Doku et al. 2023), Malawi (Ahmed et al. 2024a), Nigeria (Adejumo et al. 2023), Tanzania (Bintabara and Ngajilo 2020), and Uganda (Rogers et al. 2018). Diagnostic capacity was undermined by equipment shortages, irregular maintenance, and consumable stockouts; factors that limit the health system's capacity to detect, monitor, and manage hypertension effectively. These gaps are compounded by chronic understaffing, inadequate skill mix, and dependence on volunteers and casual workers to support service delivery. At the interface of care, lack of comprehensiveness, continuity, coordination and access to hypertension care are driven by systemic inefficiencies, high workloads, referral gaps, and unaffordable care (Oyando et al. 2019, Oyando et al. 2025). Taken together, these findings point to a system that remains inadequately capacitated to deliver equitable and high-quality hypertension care, particularly at the PHC level where early detection and continuity is most critical (Oyando et al. 2022).

Findings from our study revealed a substantial financing gap for NCDs within Kenya's health system, a challenge reported in other LMICs (Jakovljevic et al. 2019, Brathwaite et al. 2022, Amarteyfio et al. 2024). Delays in the disbursement of funds from prepaid sources such as the National Treasury and the NHIF were reported. These delays disrupted service delivery and constrained the capacity of Kilifi County's health system to provide quality, comprehensive and accessible hypertension care, reflecting concerns previously documented in Kenya (Mbau et al. 2020, Kairu et al. 2021, Oyando et al. 2023b). Prior empirical studies have shown that such fiscal bottlenecks undermine planning, procurement, and timely execution of essential health services, particularly in decentralized systems (Tsofa et al. 2017, Mbau et al. 2018). In addition, addressing delays in funding flows to subnational levels in Kenya has been identified as a critical driver to improving health system efficiency (Moses et al. 2021).

Moreover, our findings highlighted a staggering 94% funding gap in the implementation of Kenya's NCD strategy (Ministry of Health 2021), which may partly explain observed hardware constraints such as commodity shortages and tangible software deficiencies, including inadequate training and supervision of FLHWs. The under-prioritization of NCDs and budget constraints reported in our study illustrate the CAS principle of path dependence where decisions about resource allocation reflect historical priorities making it difficult to reallocate funds for emerging NCDs burden. Limited resources and growing expectations generate system strain, with feedback loops between budget gaps and service interruptions contributing to limited health system capacity to respond to the growing NCD burden.

In the context of growing public debt, declining donor support and as countries strive towards attaining universal health coverage, there has been a growing emphasis on domestic resource mobilization (Savedoff et al. 2025). Increasing excise taxes on harmful products such as tobacco, alcohol, and sugar-sweetened beverages has emerged as one of the viable strategies to generate sustainable financing for health, including NCD prevention and control (Allen 2017, Blecher et al. 2023). This is particularly relevant for Kenya where prepayment financing mechanisms through health insurance are unresponsive to patient needs and ineffective in protecting NCD households from catastrophic health expenditures (Oyando et al. 2023a, Oyando et al. 2023b). The recent World Health Organization's launch of the '3 by 35' initiative that urges countries to increase the real prices of these harmful products by at least 50% by 2035 has cemented the position of health taxes as a global policy goal (World Health Organisation 2025).

Several countries, including Ethiopia, South Africa, the Philippines, Mexico, and Thailand, have successfully implemented such taxes with significant health and fiscal benefits (Sánchez-Romero et al. 2016, Saxena et al. 2019, Phonsuk et al. 2021, Chakrabarti et al. 2022, Boachie et al. 2024). Nonetheless, concerns persist about the potentially regressive nature of health taxes, that is, their disproportionate impact on poorer populations (Verguet et al. 2021). In our study, respondents recommended earmarking potential revenues from these taxes specifically for health spending to tackle the growing NCDs burden. Addressing concerns about regressivity requires context-specific empirical evidence on the distributional effects of excise tax policies in Kenya. Future research should also conduct a political economy analysis of implementing and sustaining health taxes, including stakeholder interests, governance frameworks, and the transparency of revenue use.

Theoretical and conceptual reflections

The integration of the Elloker et al. (2012) framework with CAS theory (Begun et al. 2003) provided a robust lens for interpreting the findings. The Elloker framework helped categorize the constituent elements of health system capacity, while CAS theory illuminated the dynamic, nonlinear, and emergent interactions among these elements. Key CAS properties—such as self-organization, emergence, and nonlinearity were evident in the adaptive behaviours of FLHWs and facility managers. For example, the establishment of MTM clinics and the borrowing of BP machines from community members illustrate self-organization in response to systemic gaps. However, these adaptations also revealed fragility and inequity, particularly when unsupported by institutional mechanisms. The findings of our study also highlight the concept of path dependence, where historical prioritization of communicable diseases continues to shape budgetary decisions, undermining the system's responsiveness to the growing NCD burden. This reinforces the need to view health systems not as static entities but as evolving networks of interdependent agents.

Policy and practice implications

Drawing from our findings, we provide several recommendations for policy and practice. First, to reduce the existing NCD financing gap, there is a need for the government of Kenya to adopt fiscal policy reforms to increase domestic resource mobilization. Options for fiscal space expansion through health taxes that have shown promise in some settings (Stacey et al. 2018, Chakrabarti et al. 2022, Boachie et al. 2024) should be explored for feasibility. Second, for improved and uninterrupted service delivery for hypertension, measures to reduce inefficiencies, such as delays in disbursements of funds from prepaid sources from the National Treasury, should be urgently implemented. Third, strengthening health system capacity for NCDs requires investment in both hardware (e.g. infrastructure and information systems) and software (e.g. FLHW training). Fourth, as policies such as primary care networks are rolled out in the country, there is a need to strengthen the capacity of PHC facilities to enhance access to hypertension care, including the stocking of essential antihypertensives.

Study strengths and limitations

This study is, to our knowledge, the first qualitative exploration of health system capacity for NCDs using a hardware-software framing and CAS theory—a key strength. Applying complexity theory provided a more nuanced perspective than traditional approaches by highlighting the interconnected nature of actors and processes rather than isolating causes. Another strength lies in examining capacity from multiple perspectives with diverse data collection methods. Trustworthiness was enhanced through member-checking and an audit trail of data collection and analysis. Still, our findings should be interpreted with limitations in mind. Focusing on a single county, though intentional, may restrict generalizability but allowed in-depth, context-rich insights that broader studies might miss. Additionally, applying complexity theory *post hoc*, rather than integrating it into data collection design, may have limited data completeness and reduced opportunities to analyse findings through varied lenses.

Conclusions

This study underscores the importance of adopting a complexity-informed approach to assessing health system capacity for NCDs. By applying CAS theory and the Elloker et al. (2012) framework, we reveal that capacity is not merely a function of available resources but emerges from the dynamic interplay of hardware and software elements. Therefore, strengthening health system for NCDs requires coordinated investment in both hardware (e.g. financing, infrastructure) and software (e.g. FLHW training, leadership) elements of the health system. Importantly, rather than strengthening isolated elements of the system, interventions should consider the CAS nature of health systems to foster conditions for productive emergence.

Acknowledgements

We thank the IHCoR-Africa collaborators (Adrianna Murphy, Andrew Prentice, Alexander Perkins, Anoop Shah, Assan Jaye, David Leon, Emily Herrett, Melanie Morris, Modou Jobe, and Tim Clayton) for their continued support to the project. We thank Kenyan health authorities, people living with hypertension and stakeholders for their time during data collection and participation in workshops.

Author contributions

Conception or design of the work: R.O., E.B., B.T., E.N., P.P., and A.E. Data collection: R.O. and N.K. Data analysis and interpretation: R.O., N.K., B.D., S.H., J.B., R.L., N.M., S.K., A.E., P.P., E.B., E.N., and B.T. Drafting the article: R.O. Critical revision of the article: R.O., N.K., E.B., B.T., E.N., P.P., and A.E. Final approval of the version to be submitted: R.O., N.K., B.D., S.H., J.B., R.L., N.M., S.K., A.E., P.P., E.B., E.N., and B.T.

Supplementary data

Supplementary material is available at *Health Policy and Planning* online.

Conflicts of interest

The authors declare that they have no conflict of interest.

Funding

This project is funded by the National Institute for Health and Care Research (NIHR) under its 'Global Health Research Units and Groups Programme' (Grant Reference Number NIHR134544). The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Data availability

The data underlying this article cannot be shared publicly to ensure the privacy of individuals that participated in the study. Data are, however, available from the authors upon reasonable request and with permission of KEMRI Wellcome Trust Data Governance Committee.

Consent for publication

This manuscript was written with the permission of Director KEMRI CGMRC.

Ethical approval

The study received ethical clearance from three bodies: the KEMRI Scientific and Ethics Review Unit (Reference No. 4631), the LSHTM Ethics Committee (Reference No. 28313), and NACOSTI (Reference No. NACOSTI/P/23/24745). In addition, administrative permissions were obtained from the County Director of Health, county and sub-county health management teams, and facility managers of participating health facilities. All participants were provided with detailed study information and gave written informed consent prior to participation.

Reflexivity statement

The group of authors includes five females and seven males. The group comprises researchers from three countries, Kenya, The Gambia, and the United Kingdom with varying levels of experience and seniority in health economics, health systems and policy research, clinical epidemiology, and health services management. Two members of the authorship team are Ph.D. candidates. The researchers' areas of study are varied and include health financing, health system governance, analysis of health policy and its implementation in LMIC health systems, health services, hypertension and cardiovascular health and community engagement.

References

Adam T, de Savigny D. Systems thinking for strengthening health systems in LMICs: need for a paradigm shift. *Health Policy Plan* 2012;**27**:iv1–3. https://doi.org/10.1093/heapol/czs084

Adejumo O, Ogundele O, Mamven M *et al.* Assessment of hypertension service availability in some primary health centres in Nigeria: a mixed-methods study. *BMJ Open* 2023;**13**: e073833. https://doi.org/10.1136/bmjopen-2023-073833

AFIDEP 2023. Status of Domestic Health Financing in Kenya: County Analysis. Available at: https://shorturl.at/OdqYI (Accessed on 12 September 2025).

Ahmed S, Cao Y, Wang Z *et al.* Service readiness for the management of non-communicable diseases in publicly financed facilities in Malawi: findings from the 2019 harmonised health facility assessment census survey. *BMJ Open* 2024a;**14**: e072511. https://doi.org/10.1136/bmjopen-2023-072511

Ahmed SM, Krishnan A, Karim O *et al.* Delivering noncommunicable disease services through primary health care in selected south Asian countries: are health systems prepared? *Lancet Glob Health* 2024b;**12**:e1706–19. https://doi.org/10.1016/S2214-109X(24)00118-9

Ali MK, Rabadan-Diehl C, Flanigan J *et al.* Systems and capacity to address noncommunicable diseases in low-and middle-income countries. *Sci Transl Med* 2013;**5**:181cm4–-181cm4. https://doi.org/10.1126/scitranslmed.3005121

Allen LN. Financing national non-communicable disease responses. *Glob Health Action* 2017;**10**:1326687. https://doi.org/10.1080/16549716.2017.1326687

Amarteyfio KNAA, Bondzie EPK, Reichenberger V *et al.* Factors influencing access, quality and utilisation of primary healthcare for patients living with hypertension in West Africa: a scoping review. *BMJ Open* 2024;**14**:e088718. https://doi.org/10.1136/bmjopen-2024-088718

Ammoun R, Wami WM, Otieno P *et al.* Readiness of health facilities to deliver non-communicable diseases services in Kenya: a national cross-sectional survey. *BMC Health Serv Res* 2022;**22**:1–11. https://doi.org/10.1186/s12913-022-08364-w

Aragón AO, Giles Macedo JC. A 'systemic theories of change'approach for purposeful capacity development. *IDS Bull (1975)*2010;**41**:87–99. https://doi.org/10.1111/j.1759-5436.2010.00140.x

Asefa A, Mcpake B, Langer A *et al.* Imagining maternity care as a complex adaptive system: understanding health system constraints to the promotion of respectful maternity care. *Sex Reprod Health Matters* 2020;**28**:e1854153. https://doi.org/10.1080/26410397.2020.1854153

Barasa EW, Molyneux S, English M *et al.* Hospitals as complex adaptive systems: a case study of factors influencing priority setting practices at the hospital level in Kenya. *Soc Sci Med* 2017;**174**:104–12. https://doi.org/10.1016/j.socscimed.2016.12.026

Begun JW, Zimmerman B, Dooley K. Health care organizations as complex adaptive systems. *Adv Health Care Organ Theory* 2003;**253**:288. https://adaptknowledge.com/wp-content/uploads/rapidintake/PI_CL/media/Begun_Zimmerman_Dooley.pdf (16 February 2026, date last accessed).

Bintabara D, Ngajilo D. Readiness of health facilities for the outpatient management of non-communicable diseases in a low-resource setting: an example from a facility-based cross-sectional survey in Tanzania. *BMJ Open* 2020;**10**:e040908. https://doi.org/10.1136/bmjopen-2020-040908

Blecher E, Ceren O, Danielle B. Unpacking the empirics behind health tax revenue. 2023. https://thedocs.worldbank.org/en/

doc/f1f068e38935e2f5d92b7edf365d5089-0350032023/kn4-health-tax-revenues (26 July 2025, date last accessed).

Boachie MK, Hofman K, Goldstein S *et al.* Modelling the potential impact of a tax on fruit juice in South Africa: implications for the primary prevention of type 2 diabetes and health financing. *BMC Nutr* 2024;**10**:145. https://doi.org/10.1186/s40795-024-00941-y

Bovet P, Houinato D, Mondo C *et al.* Availability of protocols, equipment and medicines for cardiovascular disease risk management in primary care health facilities in nine African countries. *Ann Cardiol Vasc Med* 2021;**4**:1043. https://www.meddocsonline.org/annals-of-cardiology-and-vascular-medicine/availability-of-protocols-equipment-and.pdf

Brathwaite R, Hutchinson E, Mckee M *et al.* The long and winding road: a systematic literature review conceptualising pathways for hypertension care and control in low-and middle-income countries. *Int J Health Policy Manag* 2022;**11**:257. https://doi.org/10.34172/ijhpm.2020.105

Burger N, Gilson L. How has the concept of health system software been used in health policy and systems research? A scoping review. *Health Policy Plan* 2025;**40**:391–408. https://doi.org/10.1093/heapol/czaf001

Chakrabarti A, Memirie ST, Yigletu S *et al.* The potential distributional health and financial benefits of increased tobacco taxes in Ethiopia: findings from a modeling study. *SSM Popul Health* 2022;**18**:101097. https://doi.org/10.1016/j.ssmph.2022.101097

Chham S, Van Olmen J, Van Damme W *et al.* Scaling-up integrated type-2 diabetes and hypertension care in Cambodia: what are the barriers to health system performance? *Front Public Health* 2023;**11**:1136520. https://doi.org/10.3389/fpubh.2023.1136520

County Government of Kilifi. Kilifi County health sector review task force: the taskforce report. 2023.

Dalglish SL, Khalid H, Mcmahon SA. Document analysis in health policy research: the READ approach. *Health Policy Plan* 2020;**35**:1424–31. https://doi.org/10.1093/heapol/czaa064

Diallo BA, Hassan S, Kagwanja N *et al.* Managing hypertension in rural Gambia and Kenya: protocol for a qualitative study exploring the experiences of patients, health care workers, and decision-makers. *NIHR Open Res* 2024;**4**:5. https://doi.org/10.3310/nihropenres.13523.1

Doku A, Tuglo LS, Chilunga F *et al.* A multilevel and multicenter assessment of health care system capacity to manage cardiovascular diseases in Africa: a baseline study of the Ghana heart initiative. *BMC Cardiovasc Disord* 2023;**23**:421. https://doi.org/10.1186/s12872-023-03430-5

Elloker S, Olckers P, Gilson L *et al.* Crises, routines and innovations: the complexities and possibilities of sub-district management. *S Afr Health Rev* 2012;**2012**:161–73. https://hdl.handle.net/10520/EJC133690

Etyang AO, Munge K, Bunyasi EW *et al.* Burden of disease in adults admitted to hospital in a rural region of coastal Kenya: an analysis of data from linked clinical and demographic surveillance systems. *Lancet Glob Health* 2014;**2**:e216–24. https://doi.org/10.1016/S2214-109X(14)70023-3

Gilson L. Health Policy and Systems Research: A Methodology Reader. Alliance HPSR/WHO, Geneva, Switzerland, 2012, 474 pp. https://shorturl.at/fGofc (16 February 2026, date last accessed).

Gilson L, Barasa E, Nxumalo N *et al.* Everyday resilience in district health systems: emerging insights from the front lines in Kenya and South Africa. *BMJ Glob Health* 2017;**2**:e000224. https://doi.org/10.1136/bmjgh-2016-000224

Government of Kenya. The Facilities Improvement Financing Act No 14 of 2023. 2023a. https://shorturl.at/k9NGG (9 April 2025, date last accessed).

Government of Kenya. Primary Health Care Act No. 13 of 2023. 2023b. https://new.kenyalaw.org/akn/ke/act/2023/13/eng@2023-11-24#part_VI (11 February 2024, date last accessed).

Government of Kenya. The Constitution of Kenya, 2010. Nairobi, Kenya: Government Press, 2010.

Greenhalgh T, Papoutsi C. Studying complexity in health services research: desperately seeking an overdue paradigm shift. *BMC Med* 2018;**16**:95. https://doi.org/10.1186/s12916-018-1089-4

Gupta N, Coates MM, Bekele A *et al.* Availability of equipment and medications for non-communicable diseases and injuries at public first-referral level hospitals: a cross-sectional analysis of service provision assessments in eight low-income countries. *BMJ Open* 2020;**10**:e038842. https://doi.org/10.1136/bmjopen-2020-038842

Hodiamont F, Jünger S, Leidl R *et al.* Understanding complexity–the palliative care situation as a complex adaptive system. *BMC Health Serv Res* 2019;**19**:1–14. https://doi.org/10.1186/s12913-019-3961-0

Jakovljevic M, Jakab M, Gerdtham U *et al.* Comparative financing analysis and political economy of noncommunicable diseases. *J Med Econ* 2019;**22**:722–7. https://doi.org/10.1080/13696998.2019.1600523

Kabir A, Karim MN, Islam RM *et al.* Health system readiness for non-communicable diseases at the primary care level: a systematic review. *BMJ Open* 2022;**12**:e060387. https://doi.org/10.1136/bmjopen-2021-060387

Kagwanja N, Waithaka D, Nzinga J *et al.* Shocks, stress and everyday health system resilience: experiences from the Kenyan coast. *Health Policy Plan* 2020;**35**:522–35. https://doi.org/10.1093/heapol/czaa002

Kairu A, Orangi S, Mbuthia B *et al.* Examining health facility financing in Kenya in the context of devolution. *BMC Health Serv Res* 2021;**21**:1086. https://doi.org/10.1186/s12913-021-07123-7

Lindberg C, Nash S, Lindberg C. On the Edge: Nursing in the Age of Complexity. Create Space Independent Publishing Platform, 2008.

Marion R. The Edge of Organization: Chaos and Complexity Theories of Formal Social Systems. SAGE Publications, Incorporated, 1999. ProQuest Ebook Central. https://ebookcentral.proquest.com/lib/open/detail.action?docID=997031 (16 February 2026, date last accessed).

Marion R, Bacon J. Organizational extinction and complex systems. *Emergence* 1999;**1**:71–96. https://doi.org/10.1207/s15327000em0104_5

Mbau R, Barasa E, Munge K *et al.* A critical analysis of health care purchasing arrangements in Kenya: a case study of the county departments of health. *Int J Health Plann Manage* 2018;**33**:1159–77. https://doi.org/10.1002/hpm.2604

Mbau R, Kabia E, Honda A *et al.* Examining purchasing reforms towards universal health coverage by the national hospital

insurance fund in Kenya. *Int J Equity Health* 2020;**19**:19. https://doi.org/10.1186/s12939-019-1116-x

Mclennan S, Movono A, Thomas-Maude J *et al*. 2023. "Nobody should talk about it": Fijian health system resilience and the COVID-19 pandemic. 2023. http://hdl.handle.net/10179/18292 (26 February 2026, date last accessed).

Meyer A-M, Davis M, Mays GP. Defining organizational capacity for public health services and systems research. *J Public Health Manag Pract* 2012;**18**:535–44. https://doi.org/10.1097/PHH.0b013e31825ce928

Ministry of Health. Kenya Health Policy 2014–2030. 2014. https://repository.kippra.or.ke/handle/123456789/4681 (16 February 2026, date last accessed).

Ministry of Health. Kenya Universal Health Coverage (UHC) Policy 2020–2030: Accelerating Attainment of Universal Health Coverage. Afya House, Cathedral Road, P.O. Box 30016–00100, Nairobi. 2020. http://www.health.go.ke/ (17 February 2026, date last accessed).

Ministry of Health. National Strategic Plan for the Prevention and Control of Non-Communicable Diseases 2021/22–2025/26. 2021. https://shorturl.at/kNhwt (8 April 2025, date last accessed).

Ministry of Health. Kenya Essential Medicines List. Cathedral Road, Nairobi, Kenya: Afya House, 2023.

Ministry of Health. Kenya National Guidelines for the Management of Cardiovascular Diseases. 2024a. http://guidelines.health.go.ke:8000/media/2024_KENYA_NATIONAL_GUIDELINES_FOR_CVD_MANAGEMENT_3.pdf (17 February 2026, date last accessed).

Ministry of Health. National and County Health Budget Analysis, FY 2023/24. Nairobi. 2024b. https://shorturl.at/JVCwE (12 September 2025, date last accessed).

Moses MW, Korir J, Zeng W *et al.* Performance assessment of the county healthcare systems in Kenya: a mixed-methods analysis. *BMJ Glob Health* 2021;**6**:e004707. https://doi.org/10.1136/bmjgh-2020-004707

Moturi AK, Suiyanka L, Mumo E *et al.* Geographic accessibility to public and private health facilities in Kenya in 2021: an updated geocoded inventory and spatial analysis. *Front Public Health* 2022;**10**:1002975. https://doi.org/10.3389/fpubh.2022.1002975

Mutale W, Bosomprah S, Shankalala P *et al.* Assessing capacity and readiness to manage NCDs in primary care setting: gaps and opportunities based on adapted WHO PEN tool in Zambia. *PLoS One* 2018;**13**:e0200994. https://doi.org/10.1371/journal.pone.0200994

Mwamba C, Sharma A, Mukamba N *et al.* They care rudely!': resourcing and relational health system factors that influence retention in care for people living with HIV in Zambia. *BMJ Glob Health* 2018;**3**:e001007. https://doi.org/10.1136/bmjgh-2018-001007

Orji IA, Baldridge AS, Omitiran K *et al.* Capacity and site readiness for hypertension control program implementation in the Federal Capital Territory of Nigeria: a cross-sectional study. *BMC Health Serv Res* 2021;**21**:1–12. https://doi.org/10.1186/s12913-021-06320-8

Oyando R, Barasa E, Ataguba JE. Socioeconomic inequity in the screening and treatment of hypertension in Kenya: evidence from a national survey. *Front Health Serv* 2022;**2**:786098. https://doi.org/10.3389/frhs.2022.786098

Oyando R, Kagwanja N, Diallo BA *et al.* Access to hypertension services and health-seeking experiences in rural Coastal Kenya: a qualitative study. *PLOS Glob Public Health* 2025;**5**:e0004324. https://doi.org/10.1371/journal.pgph.0004324

Oyando R, Njoroge M, Nguhiu P *et al.* Patient costs of hypertension care in public health care facilities in Kenya. *Int J Health Plann Manage* 2019;**34**:e1166–78. https://doi.org/10.1002/hpm.2752

Oyando R, Were V, Koros H *et al.* Evaluating the effectiveness of the national health insurance fund in providing financial protection to households with hypertension and diabetes patients in Kenya. *Int J Equity Health* 2023a;**22**:107. https://doi.org/10.1186/s12939-023-01923-5

Oyando R, Were V, Willis R *et al.* Examining the responsiveness of the national health insurance fund to people living with hypertension and diabetes in Kenya: a qualitative study. *BMJ Open* 2023b;**13**:e069330. https://doi.org/10.1136/bmjopen-2022-069330

Peck R, Mghamba J, Vanobberghen F *et al.* Preparedness of Tanzanian health facilities for outpatient primary care of hypertension and diabetes: a cross-sectional survey. *Lancet Glob Health* 2014;**2**:e285–92. https://doi.org/10.1016/S2214-109X(14)70033-6

Perkins AD, Awori JO, Jobe M *et al.* Determining the optimal diagnostic and risk stratification approaches for people with hypertension in two rural populations in Kenya and The Gambia: a study protocol for IHCoR-Africa work package 2. *NIHR Open Res* 2023;**3**:68. https://doi.org/10.3310/nihropenres.13509.1

Phonsuk P, Vongmongkol V, Pongutta S *et al.* Impacts of a sugar sweetened beverage tax on body mass index and obesity in Thailand: a modelling study. *PLoS One* 2021;**16**:e0250841. https://doi.org/10.1371/journal.pone.0250841

Plsek PE, Greenhalgh T. The challenge of complexity in health care. *BMJ* 2001;**323**:625–8. https://doi.org/10.1136/bmj.323.7313.625

Pope C, Ziebland S, Mays N. Analysing qualitative data. *BMJ* 2000;**320**:114–6. https://doi.org/10.1136/bmj.320.7227.114

Rogers HE, Akiteng AR, Mutungi G *et al.* Capacity of Ugandan public sector health facilities to prevent and control non-communicable diseases: an assessment based upon WHO-PEN standards. *BMC Health Serv Res* 2018;**18**:606. https://doi.org/10.1186/s12913-018-3426-x

Rusoja E, Haynie D, Sievers J *et al.* Thinking about complexity in health: a systematic review of the key systems thinking and complexity ideas in health. *J Eval Clin Pract* 2018;**24**:600–6. https://doi.org/10.1111/jep.12856

Sánchez-Romero LM, Penko J, Coxson PG *et al.* Projected impact of Mexico's sugar-sweetened beverage tax policy on diabetes and cardiovascular disease: a modeling study. *PLoS Med* 2016;**13**:e1002158. https://doi.org/10.1371/journal.pmed.1002158

Savedoff W, Yazbeck AS, Peters DH *et al.* Development assistance for health and the challenge of NCDs through the Lens of type 2 diabetes. *Health Syst Reform* 2025;**11**:2531693. https://doi.org/10.1080/23288604.2025.2531693

Saxena A, Koon AD, Lagrada-Rombaua L *et al.* Modelling the impact of a tax on sweetened beverages in the Philippines: an extended cost-effectiveness analysis. *Bull World Health Organ* 2019;**97**:97–107. https://doi.org/10.2471/BLT.18.219980

Scott JAG, Bauni E, Moisi JC *et al.* Profile: the Kilifi health and demographic surveillance system (KHDSS). *Int J Epidemiol* 2012;**41**:650–7. https://doi.org/10.1093/ije/dys062

Sheikh K, Gilson L, Agyepong IA *et al.* Building the field of health policy and systems research: framing the questions. *PLoS Med*2011;**8**:e1001073. https://doi.org/10.1371/journal.pmed.1001073

Stacey N, Summan A, Tugendhaft A *et al.* Simulating the impact of excise taxation for disease prevention in low-income and middle-income countries: an application to South Africa. *BMJ Glob Health* 2018;**3**:e000568. https://doi.org/10.1136/bmjgh-2017-000568

Sturmberg JP, Bircher J. Better and fulfilling healthcare at lower costs: the need to manage health systems as complex adaptive systems. *F1000Res* 2019;**8**:789. https://doi.org/10.12688/f1000research.19414.1

Tesema AG, Abimbola S, Mulugeta A *et al.* Health system capacity and readiness for delivery of integrated non-communicable disease services in primary health care: a qualitative analysis of the Ethiopian experience. *PLoS Glob Public Health* 2021;**1**:e0000026. https://doi.org/10.1371/journal.pgph.0000026

Tesema AG, Joshi R, Abimbola S *et al.* Readiness for non-communicable disease service delivery in Ethiopia: an empirical analysis. *BMC Health Serv Res* 2024;**24**:1021. https://doi.org/10.1186/s12913-024-11455-5

Tsofa B, Molyneux S, Gilson L *et al.* How does decentralisation affect health sector planning and financial management? A case study of early effects of devolution in Kilifi County, Kenya. *Int J Equity Health* 2017;**16**:151. https://doi.org/10.1186/s12939-017-0649-0

Verguet S, Kearns PK, Rees VW. Questioning the regressivity of tobacco taxes: a distributional accounting impact model of increased tobacco taxation. *Tob Control* 2021;**30**:245–57. https://doi.org/10.1136/tobaccocontrol-2019-055315

Weick KE. Educational organizations as loosely coupled systems. *Adm Sci Q* 1976;**21**:1–19. https://doi.org/10.2307/2391875

Williams KN, Tenorio-Mucha J, Campos-Blanco K *et al.* Health system barriers to hypertension care in Peru: rapid assessment to inform organizational-level change. *PLoS Glob Public Health* 2024;**4**:e0002404. https://doi.org/10.1371/journal.pgph.0002404

World Health Organisation. 2025. WHO launches bold push to raise health taxes and save millions of lives. Available at: https://shorturl.at/ZdhGC (Accessed on 12 September 2025)

World Health Organization. *Service availability and readiness assessment (SARA): an annual monitoring system for service delivery: reference manual* (No. WHO/HIS/HSI/RME/2013/1). World Health Organization. 2013. https://www.who.int/data/data-collection-tools/service-availability-and-readiness-assessment-(sara) (17 February 2026, date last accessed).

World Health Organization 2025. Non-communicable diseases. Retrived from: https://www.who.int/health-topics/noncommunicable-diseases#tab=tab_1 (Accessed 15 July 2025).

Zimmerman B, Glouberman S. Complicated and complex systems: what would successful reform of medicare look like. In: Health Care Services and the Process of Change. Toronto: University of Toronto Press, 2004, 21–53.