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Understanding healthcare demand and supply through causal loop diagrams and system archetypes: policy implications for kidney replacement therapy in Thailand

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Abstract

Background Systems thinking approaches can determine system interdependencies to guide effective policy-making but have been underutilised in health policymaking, particularly for policies related to access and delivery of health services. In Thailand, a policy changing access to dialysis services for patients with kidney failure in 2022 had resulted in an unexpected surge in patients, mortality rate, and budget overspend. This study applied systems thinking to characterise the dynamics underlying the unforeseen impact of the 2022 policy, in order to propose context-specific policy interventions.

Methods We developed a causal loop diagram through iterative stakeholder engagement, to understand the drivers for supply and demand of dialysis under the 2022 policy in Thailand. Since systems thinking was considered a new tool for policymaking, we used system archetypes as a means by which to collapse down the complexity of causal loop diagrams into simple narratives for policymakers. Confidence-building (validation) was conducted through triangulation across data sources and steps to facilitate stakeholder critique throughout the process.

Results Chronic underinvestment in peritoneal dialysis had failed to capitalise on improvements in expertise and quality of services, while a series of short-term measures to overcome constraints in haemodialysis supply had unintentionally increased haemodialysis demand in the long-term, increasing strain on the healthcare system. By applying generic solution archetypes, we identified a series of measures to balance demand for services with system capacity, including better alignment of incentives with health system goals, proactive planning to anticipate future supply needs, and regulatory mechanisms to moderate demand according to available supply.

Conclusions A major implication of this research is that changes to healthcare access and delivery require multi-stakeholder engagement and whole system thinking, as even small changes can have potentially vast consequences. Applying a systems thinking lens not only communicated the reasons for unintended impact of the 2022 policy, but also identified interventions absent from the literature that were unique to the drivers of demand and supply in Thailand.

Keywords Dialysis, Health services, Complex systems, System dynamics, Causal loop diagram, Kidney replacement therapy

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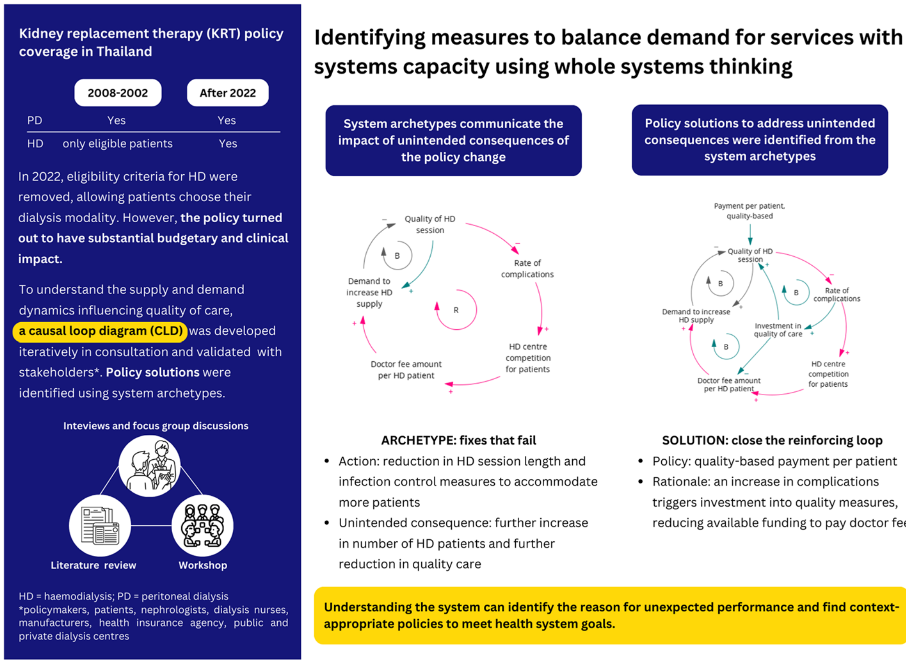
Graphical Abstract



Background

Globally, there is increasing adoption of systematic, evidence-informed priority-setting mechanisms for health [1, 2], with growing evidence of positive impact across multiple dimensions of decision-making [3–5]. Although traditionally focussed on which technologies and services to cover under publicly funded health systems or health insurance schemes [1, 6], the remit of systematic, evidence-informed priority-setting mechanisms is expanding to address issues such as organisation of healthcare delivery and health system interventions to address supply and demand of services [7, 8].

The evaluation of system interventions requires different priority-setting methods and processes [9, 10]. Technology assessment starts with an intervention, whereas system interventions often start with a context-specific issue: there may not be a clearly defined set of policy interventions or there may be questions around the transferability of successful programmes from other settings [11]. Conventional methods for priority-setting in health do not account for changes in actor behaviour or responses in other areas of the system, such as feedback loops between government sectors [12, 13], the effect of incentives on actor behaviour [14, 15], or changes in population values following system change [10], yet these are often key factors influencing impact of system interventions.

Healthcare systems show the features of complex systems: behaviour of the system as a whole cannot be predicted from its components; there is feedback, meaning that change can reinforce or balance further change; and adjustments to the system can modify system behaviour (adaptation) [9, 10, 16]. Furthermore, health system policy questions often exhibit the features of an unstructured problem, defined as problems with divergent stakeholder perspectives and interests, intangible elements, and uncertainty [17]. Multiple problem frames may exist, with stakeholders disagreeing about whether there is a problem, the underlying reasons for the problem, which policy body is responsible and the scope of its mandate, the solution space to explore, the evidence that should be considered, and/or appropriate stakeholders to involve for a recommendation [18]. Failing to account for system complexity or multiple problem frames can lead to policy interventions that have limited impact, or worse, exacerbate the problem in the long run [9, 12, 19].

Systems thinking is an established approach to problem-solving that determines and communicates "complex feedback structures to facilitate system change" [12]. The premise is that understanding inter-dependencies endogenous to the system and mapping a holistic view of the system from multiple stakeholder perspectives guides effective policy and decision-making [12, 20, 21]. Given the complexity of health systems, it has been proposed that systems thinking can improve health service design [9, 12, 16, 22].

Within systems thinking, causal loop diagrams (CLDs) are used as an analytical tool to surface and understand the mental models of different stakeholders about how the system works [23]. CLDs illustrate the inter-dependencies in a system, representing the collective knowledge of a group [24]. They are often used as an evolving thinking tool to structure problems, to facilitate joint stakeholder learning about complex systems and alternative problem frames, and to identify and address unintended consequences of past or future policies [19, 25, 26]. Interest in CLDs to inform healthcare policy is growing [27, 28]. CLDs have been used to explore multi-faceted healthcare problems, including inequity, provider payment, and governance [13, 14, 29]; to support health system planning [28, 30–32]; and for programme evaluation [15]. Archetypes represent common structures (combinations of loops) within a CLD that characterise behaviours that are consistent across disciplines and settings [20]. Archetypes thus support development of narratives to understand and communicate the complexity captured by a CLD [19]. For example, the *underachievement* archetype describes a CLD structure for policy actions that do not achieve the expected impact due to a delayed reaction from another area of the system. This archetype may describe, for example, a policy research institute aiming to improve its policy relevance by producing research reports in a shorter timeframe, but subsequently experiencing a loss of reputational trust from stakeholders who valued the institute's scientific rigour. Although archetypes have been applied to a certain extent to understand dynamics of health and social care in the UK [12], their application remains limited within health priority-setting globally.

In 2024, our research team was tasked with generating evidence for a policy recommendation to the National Health Security Office (NHSO) Board in Thailand regarding the kidney replacement therapy (KRT) policy, an issue that showed the features of a complex, unstructured health system problem. In Thailand, there is well-established governance to assess technologies (medical devices, surgical procedures, health promotion programmes, diagnostics, etc.) for inclusion under the Universal Coverage Scheme (UCS) benefit package. The process includes stakeholder nomination of technologies and conduct of additional studies (for example, economic evaluation for high-cost interventions or feasibility studies) to inform the final policy recommendation [33]. NHSO provides funding to public and private healthcare providers for services provided in the benefit package, which are provided free at point of care to registered beneficiaries [34]. There is, however, no formal governance for policies related to changes in service delivery or coverage.

Due to limited infrastructure for transplantation and legal restrictions on organ donation, most patients with kidney failure in Thailand receive dialysis as a life-sustaining treatment until the end of life. The KRT programme under NHSO is funded by its own budget, due to the significant costs: over 5% of the total NHSO budget is allocated each year to treat the 0.1% UCS beneficiaries with kidney failure, and this figure is expected to rise given increasing rates of chronic kidney disease [35]. Treatment of KRT complications is funded separately through an inpatient budget. Dialysis providers are paid by fee-for-service, with a higher fee for HD services. Peritoneal dialysis (PD) is provided solely by public hospitals, while haemodialysis (HD) is provided by both public and private centres. Registration and quality assurance requirements differ between public centres, private hospitals, and private clinics, with very limited regulation of private provider use of the fee-for-service.

A change to the KRT policy had been implemented in 2022, based on an estimation of marginal budget increase and minor system disruption (Teerawattananon Y, Chavarina KK, Phannajit J, et al: Nature medicine commission on dialysis policy in low- and middle-income countries: from policy to pivotal impact: Thailand's dialysis reform journey and its unexpected consequences, submitted). However, contrary to expectations, the budgetary and health system impact was substantial. The budget doubled to represent 10% of the total NHSO budget for all health conditions, and by 2024 mortality rates were still 50% higher than expected deaths [36]. Initial research indicated that lower quality of care and workforce shortages were being mutually reinforced and that actors had changed their behaviour following the policy change. This suggested the presence of feedback loops and system adaptation, typical of a complex system, which had not been accounted for in the policy design. Moreover, the reasons underlying the increased number of patients and mortality rates were contested, particularly due to the highly political nature of the policy change.

In this study, we applied system archetypes, an underused tool within healthcare policy, to understand the supply and demand dynamics in a middle-income setting with mixed public–private healthcare service provision. By applying a systems thinking lens, this study aimed to (1) identify the causal relationships driving the demand and supply for KRT services under the 2022 policy in Thailand and (2) identify policies that are likely to have greatest impact on quality of care and financial sustainability of the KRT programme.

Methods

We developed a CLD through an iterative process with stakeholders from June to October 2024, in order to inform the policy recommendations of a working group under the NHSO Board in Thailand. The decision to use a CLD as an approach was based on early discussions and research indicating the presence of feedback loops, system adaptation, and multiple stakeholder frames [36]. Although the CLD outlined in this paper was primarily used as an exploratory thinking tool, the CLD later formed the basis of a system dynamic model, which quantitatively modelled policies. An overview of the components of a causal loop diagram is provided in Table 1.

Study setting

The setting for this study was the KRT programme under the Universal Coverage Scheme (UCS) in Thailand. UCS is a tax-funded public health insurance scheme covering those who are not registered under health insurance schemes for government employees or the private sector, amounting to around 75% of the total population [37]. From 2008 to 2022, the UCS KRT programme required all KRT patients eligible for home-based peritoneal dialysis (PD) to receive PD; only those with health or social contraindications for PD could receive haemodialysis (HD) at a hospital or registered private centre [38]. This was known as the "PD-first" policy. Although the PD-first policy was successful in allowing UCS patients to access dialysis in the context of constrained resources, patient groups were increasingly vocal in demanding access to HD, particularly as the public health insurance schemes covering civil servants and private sector employees did not restrict HD access (Teerawattananon Y, Chavarina KK, Phannajit J, et al: Nature medicine commission on dialysis policy in low- and middle-income countries: from policy to pivotal impact: Thailand's dialysis reform journey and its unexpected consequences, submitted). On 1 st February 2022, in response to patient advocacy, eligibility criteria for HD were removed, with the intention that this would improve patient choice and reduce out-of-pocket spending by allowing all KRT patients to access either HD or PD without co-payment [39].

Boundaries of analysis

We considered the drivers leading to changes in the number of registered HD and PD patients following implementation of the 2022 policy, covering both demand-side (number of patients) and supply-side (availability of services) factors. Our scope was dynamics that have an effect at the national level under routine implementation of the 2022 policy, without shocks to the system, from 2022 to 2029. As the study took place from June to October 2024, this timeframe was selected to understand influential factors that had shaped the system response to the 2022 policy, as well as how those dynamics may play out over the next 5 years, to inform future policy interventions to control the impact on budget expenditures and mortality.

Since we were considering routine implementation, we excluded shocks to the system such as flooding, infectious disease outbreaks, or closure of manufacturing plants. We additionally assumed that there would be no significant change in prevalence of kidney transplantation or advancements in dialysis technology that would displace HD or PD within the study timeframe.

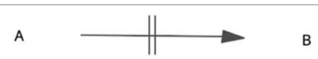
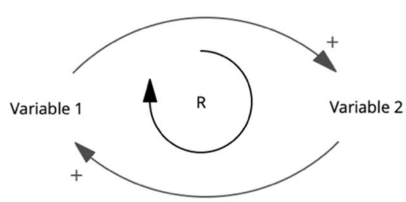
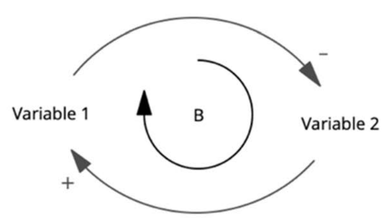
Steps to develop the CLD

The process to develop the CLD covered the following five steps: (1) development of cognitive maps from secondary interview data, (2) synthesis of cognitive maps and definition of problem boundaries, (3) development of a core CLD with analysis of system archetypes, (4) stakeholder critique of draft CLDs and revision, and (5) identification of potential solutions to improve quality of care and financial sustainability of the dialysis programme. These steps are broadly based on [23], with the addition of system archetypes as an analytical tool for sense-making [19]. Each step is described below.

Step 1: cognitive maps from secondary interview data

Cognitive maps are often used as a preliminary step to developing a causal loop diagram, to represent the mental models of individuals before engaging in a process of group sense-making [40]. We developed cognitive maps from secondary interview data from 20 informants and a focus group discussion with 12 patients, which had been conducted as part of a prior qualitative study. Informants had been selected to understand the rationale and implications of changes to Thailand's KRT policy over the past 20 years and comprised policymakers, public and private sector healthcare professionals, manufacturers, academics, and patient representatives (Additional file: Table S1). Interviews had stopped when data saturation was reached, which the researchers had defined as the point when no new themes emerged from interim analysis. Interviews had been conducted using a narrative interview style [41], in which the interviewee was encouraged to share their background and perspectives in an unstructured interview. The amount and depth of content relevant to our research question therefore varied, but the interviews served as a helpful means for the researchers to learn about the primary issues, map variables and dependencies, and highlight areas for further stakeholder discussion.

Table 1 Elements of a causal loop diagram, based on [23, 24, 27]

Component	Example	Description
Positive arrow		The plus (+) sign indicates that an increase (or decrease) in A results in a value of B that is greater (or less) than it would have been otherwise.
Negative arrow		The minus (-) sign indicates that an increase (or decrease) in A results in a value of B that is less (or greater) than it would have been otherwise.
Delay		The delay sign (parallel lines) shows that there is a delay between a change in A and an associated change in B.
Reinforcing loop		In a reinforcing loop, there are an even number of negative arrows, typically leading to exponential increase/decrease over time.
Balancing loop		In a balancing loop, there are an odd number of negative arrows, typically leading to stabilising behaviour over time.

The cognitive maps were exploratory in that they helped to understand perceptions of the problem before defining the scope of subsequent analysis. We used uncoded transcripts to develop the cognitive maps for two reasons: firstly, bounding the system too early can risk loss of contextual information, and secondly, we found that many interviews required the analyst to read between the lines [42]. Use of non-standardised processes can, however, lead to cognitive bias, arising from the analyst interpretation of both what constitutes important information and when an informant is implying causality [42]. For this reason, the preliminary causal map developed from combining all cognitive maps was first reviewed by the research team conducting the qualitative interviews before proceeding to broader stakeholder critique and review.

Step 2: synthesis of cognitive maps

Cognitive maps developed from interview data were merged into a single causal loop diagram. This process was interpretivist as opposed to using a rule-based approach for two reasons. Firstly, the use of secondary data meant that we could not account for linguistic uncertainty by prompting stakeholders to clarify definitions, meaning, or implied causality. As a result, the analyst had to consider alternative frames based on contextual information in each interview. Secondly, since the interview data had been collected for a separate research question, we considered this step to be a broad mapping of the problem space to build researcher understanding and facilitate subsequent stakeholder discussions, as opposed to an accurate representation of the system.

At this stage, if there were discrepancies between cognitive maps in terms of the relationships between variables (or multiple possible pathways if implied causality from interview data was unclear), we maintained both pathways. In cases where there were differences between cognitive maps in terms of granularity, we included the more granular version. To focus on the elements of the system causing dynamic behaviour, we removed any sections of the resulting causal loop diagram for which there were both no feedback loops present and the research team could not identify potentially missing feedback loops. Presence of team members with experience researching health systems in other settings and conducting research on dialysis in Thailand supported this step. We also explicitly defined the boundaries at this stage to focus on factors affecting number of registered HD and PD patients under UCS.

Step 3: analysis of archetypes

System archetypes were used to analyse the resulting causal loop diagram, in order to develop the narrative for stakeholder consultation. System archetypes are composed of two or more loops representing an intended consequence with a delayed unintended consequence, which is hidden by an organisational boundary from the view of those instigating the change [19]. Table 2 provides an overview of system archetypes.

Step 4: stakeholder critique and revision

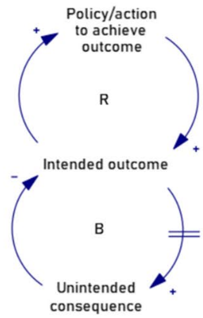
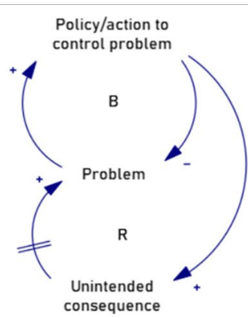
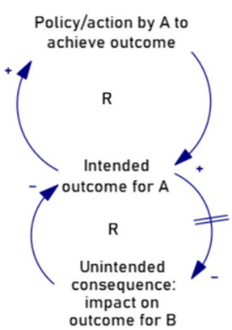
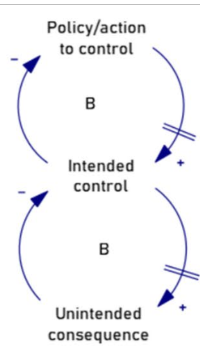
The preliminary causal loop diagram was reviewed by stakeholders during a half-day workshop on 9th July 2024. The workshop was attended by 21 participants, four of whom had already been interviewed. Compared to the interviews, the workshop included greater representation from nephrologists, dialysis nurses, and patients (Additional file: Table S2). During the workshop, participants were separated into three groups. The composition of each group aimed to encourage participation, by separating individuals from the same profession with different levels of seniority, while also including a diverse set of perspectives (for example, nephrologist, health insurance agency, manufacturer, patient). All workshop participants had been selected as stakeholders with knowledge or lived experience of the 2022 policy change and its implications. Each group reviewed the CLD (shown in Additional file: Figure S1) with two facilitators, in order to provide comments on the accuracy of connections and any missing elements. At least one facilitator in each group was conducting research into the impact of the 2022 policy.

The revised causal loop diagram was reviewed by workshop facilitators after the workshop to ensure that all contributions from their group had been sufficiently captured. Since there was conflicting information around the supply of HD services (particularly factors that influence opening of new clinics in the public and private sectors, as well as payment of a doctor fee for patient referral), we additionally circulated an anonymous survey to directors of HD centres in the public ($n=3$) and private ($n=4$) sector. We selected HD centre directors with at least 3 years of experience in the role (median 10, range 3–22) who were known to members of the research team or policy working group. For public sector centres, we only selected centres that also provided PD, and for the private sector, we chose two clinics and two hospitals. Size of HD centres in the sample ranged from 16 to 64 beds (median 20). Respondents were paid 500 THB for completing the questionnaire. All directors approached by the research team completed the survey in full. Questions included in the survey are detailed in Additional file: Table S3.

Step 5: policy solutions

Once the CLD had been finalised, we identified potential policy solutions from generic solution archetypes in the literature [19]. At the time of analysis, the working group under the NHSO Board had already started to discuss potential policy solutions based on literature reviews of experience in other countries and quantitative analysis of changes in number of patients, patient outcomes, and financial expenditures following the 2022 policy [36, 43, 44]. Initially, we checked to see whether any of the proposed policies aligned with

Table 2 Overview of system dynamics archetypes, based on [19]

#	Archetype	Diagram	Description
1	Underachievement		A policy or action does not achieve its intended impact because of an unintended consequence. This archetype consists of a reinforcing loop (planned action/policy) and a delayed balancing loop (unintended consequence of the outcome).
2	Out-of-control		A policy or action aiming to control a problem unintentionally makes the problem worse. This archetype consists of a balancing loop (policy/action) and a delayed reinforcing loop (unintended consequence of the policy/action).
3	Relative achievement		A policy or action achieves its intended impact at the expense of other policy initiatives. This archetype consists of a reinforcing loop (action/policy) and a delayed reinforcing loop (another policy/action that is undermined as a result).
4	Relative control		A policy or action aiming to control a problem undermines other policies or initiatives moderating the problem. This archetype consists of two balancing loops, representing the intended policy/action and another policy/action that is unintentionally affected. Either or both balancing loops may have a delay.

generic solution archetypes in the CLD. If no appropriate policy had yet been proposed, we proposed an additional policy intervention to align with the archetype [45]

Confidence-building

We sought to enhance validity of the CLD through triangulation across data sources (interviews, group workshop, anonymous survey, and literature review) and through steps to enhance stakeholder dialogue and understanding. During the workshop, we built up model structure sequentially, with the group facilitator providing an explanation (or "storytelling") for each view and highlighting key parts of the diagram [27, 45]. Following the workshop, the research team reviewed external validity of the CLD (when possible) by comparing with the literature, to verify whether the structure adhered to existing knowledge about the KRT system in Thailand [46].

Ethics

The Ethics Committee of the Institute for the Development of Human Research Protections (IHRP) Thailand approved the sub-study for interview data collection on February 22nd, 2024 (COA No. IHRP2024025; IHRP No.002–2567).

Results

Our analysis highlighted three main dynamic interactions influencing demand and quality of care following the 2022 policy change: (1) shifts in quality of HD service provision caused by short-term coping mechanisms to deal with the surge in HD demand; (2) mechanisms to address workforce shortages that inadvertently exacerbated system strain; and (3) development of infrastructure for HD at the expense of the PD service system. In the following sections, we outline the causal relationships underlying each of these components, applying system archetypes to identify potential solutions. Feedback loops in the CLD are summarised in Table 3 and system archetypes with potential solutions in Table 4.

Coping measures to deal with the surge in demand for HD lowered quality standards and induced further HD demand

The 2022 policy change removed eligibility criteria determining which patients could be fully reimbursed for HD. As a result, there was a surge in demand for HD, placing pressure on vascular access services (required before patients can initiate HD) as well as HD centres. A series of short-term measures were taken by the public health insurance agency (NHSO), private HD centres, and doctors to cope with the increase in demand. However, as shown in Fig. 1a, certain key measures had unintended consequences that controlled the problem in the short term but exacerbated the supply constraints in the long term. These measures are characteristic of the *out-of-control archetype* (B1/R1, B2/R2, B3/R3, and B4/R4), in which a balancing loop is counteracted by a delayed reinforcing loop, and that of the *relative-control archetype* (drifting goal as a special case, B1/B2).

The first coping measure had been taken by NHSO prior to 2022. Regulations to approve a new HD centre were relaxed, allowing HD centres to provide services without Thailand Renal Replacement Therapy (TRT) certification (balancing loop B1), in order to accelerate approval of new HD centres given the limited capacity for quality assurance (QA).

> "ปี 63 ยกเลิกใช้ใบ ตรต. ทำให้มีหลายที่ไม่ได้ขึ้นทะเบียนหน่วย และเข้า สปสช. ได้เลยในบางเขต ทำให้มีปัญหาในเทศบาล ที่จะตั้งเป็น รพ. ที่จัดตั้งไม่ได้ ไม่มีคนช่วยดูการขึ้นทะเบียน ถ้า *outsource* ไม่ยื่นตรวจ ตรต. ก็จบ"
> *"In 2020, the requirement for TRT certification was abolished, causing many centres to provide services to NHSO without TRT registration. [The TRT certificate] had been causing problems in certain municipalities that were setting up hospitals that could not be established as there was no one to facilitate the registration. If the centre manager did not submit a TRT registration report, it was over."*
> *Kidney Association representative (the Kidney Association is responsible for the management of TRT), workshop on 9th July 2024*

However, this policy unintentionally increased demand for HD: the opening of private HD clinics meant that more patients could access HD, putting pressure on NHSO to maintain the lower QA standards (reinforcing loop R1). Perhaps more importantly, B1 and B2 form a *relative control archetype*, in which actions to control the inadequate QA system distracted away from investment in QA capacity to regulate the growing number of HD centres. This illustrates the archetype of *drifting goals* (i.e., a special case of *relative control archetype*), in which targets are lowered for short-term impact instead of addressing the fundamental problem (inadequate QA capacity). In the longer term, this could lower the perceived importance of regulatory mechanisms (reinforcing loop R2), leading to chronic underinvestment in QA. This is a case of *shifting the burden* archetype, in which the short-term fix undermines fundamental solutions.

The second set of measures to address the surge in HD demand was taken by private HD centres. HD centres are reimbursed per HD session [47], creating a system in which the goal is to increase number of HD sessions

Table 3 Overview of reinforcing loops and balancing loops in the causal loop diagram. For each loop, it is noted whether the loop describes an intended or unintended consequence of a policy/action, or an initiative beyond the organisational boundary of stakeholders implementing a particular policy or action

Loop	Variables	Description
Balancing loops		
B1	3 → 4 → 3	Stringency of regulations to approve new HD centres determines pressure on the registration system (intended control measure)
B2	3 → 7 → 3	Investment in quality assurance capacity affects the adequacy of the quality assurance system (initiative outside organisational boundary)
B3	1 → 10 → 1	Quality of HD services (predominantly session length and adherence to infection control measures) is influenced by level of demand for HD services (intended control action)
B4	15 → 16 → 15	Providing HD patients with temporary access (via a catheter) affects demand for vascular access (intended control action)
B5	5 → 2 → 5	Changes in supply of HD services affect the deficit of HD nurses (unintended consequence)
B6	2 → 18 → 2	The magnitude of the HD nurse deficit influences the level of overlapping nurse shifts and overtime work for HD nurses (intended control action)
B7	2 → 19 → 20 → 2	Number of HD nurses trained depends on demand for HD nurses (initiative outside of organisational boundary)
B8	2 → 17 → 2	Deficit of HD nurses affects the rate at which PD nurses switch to HD (system control measure)
B9	23 → 24 → 22 → 23	Adequacy of the PD system for number of PD patients affects PD quality of care (system response to changes in number of PD patients)
B10	24 → 25 → 26 → 24	Investment in PD capacity depends on perceived adequacy of PD system (intended control action)
Reinforcing loops		
R1	3 → 4 → 5 → 6 → 1 → 3	Changes in regulations to approve new HD centres can induce demand for HD services (unintended consequence)
R2	3 → 4 → 8 → 7 → 3	Changes in regulations to approve new HD centres influence investment in quality assurance capacity (unintended consequence)
R3	1 → 10 → 11 → 12 → 13 → 1	Quality of HD service provision affects financial incentives for doctors to refer patients for HD (unintended consequence)
R4	15 → 16 → 17 → 15	Number of HD patients with temporary access alters long-term demand for vascular access services (unintended consequence)
R5	15 → 16 → 11 → 12 → 13 → 1 → 15	Changes in number of patients with temporary HD access influences financial incentives for doctors to refer patients for HD (unintended consequence)
R6	3 → 4 → 5 → 12 → 13 → 1 → 3	Changes in HD supply influence financial incentives for doctors to refer patients for HD (unintended consequence)
R7	2 → 18 → 21 → 20 → 2	Measures to cope with HD nurse deficit affect rates of HD nurse burnout (unintended consequence)
R8	2 → 18 → 11 → 12 → 13 → 1 → 5 → 2	Measures to cope with HD nurse deficit influence financial incentives for doctors to refer patients to HD (unintended consequence)
R9	2 → 17 → 22 → 23 → 1 → 5 → 2	Rate at which PD nurses switch to HD influences level of demand to increase HD supply (consequence of system change)
R10	23 → 27 → 22 → 23	Quality of PD depends on level of experience and culture for PD (system response)
Solution loops		
B1a	3 → S1 → 1 → 3	Pre-authorisation of patients according to available supply controls pressure on regulatory system
B2a	7 → S2b → 7	With key performance indicators (KPI) for the adequacy of quality assurance mechanisms, adequacy of registration systems to meet demand affects level of investment in quality assurance mechanisms
B3a	10 → 11 → S3b → 10	With quality-based payments per patient to HD service providers, rate of complications affects level of investment in quality of care
B3b	1 → 10 → 11 → S3b → 13 → 14 → 1	Investment in quality of care affects financial incentives for doctors to refer patients to HD
B4a	16 → 11 → 16	With quality-based payments per patient to HD service providers, rate of complications regulates number of HD patients with temporary access
B4b	15 → S1 → 1 → 15	Pre-authorisation of patients according to available supply controls pressure on vascular access services

Table 3 (continued)

Loop	Variables	Description
B6a	2 → 18 → S5b → S5c → 21 → 20 → 2	With enforceable regulations restricting HD patients per nurse and HD nurse maximum hours per week, punishment for HD centres not adhering to the rules regulates level of HD nurse burnout
B7a	19 → 20 → S4b → 19	Performance indicators linked to availability of trained HD nurses for the Ministry of Public Health regulate HD nurse training relative to nurse deficit
B8a	18 → 11 → S3c → 18	Demand forecasting for HD nurse training by the Ministry of Public Health changes nurses trained according to anticipated demand for HD services
B9a	2 → 17 → 22 → 23 → 1 → S4b → 19 → 20 → 2	With a KPI target for HD nurse to patient ratio, changes in HD demand influence HD nurse training
R9a	23 → S7 → 1 → 17 → 22 → 23	Pre-authorisation of patients initiating HD provides external regulatory control to the balance of PD to HD patients
R10a	23 → 26 → 24 → 22 → 23	Proactive forecasting for PD capacity links investment in PD infrastructure and nurses to anticipated need

per centre. To address the high demand for HD, certain private centres reduced the length of HD sessions and cut back on infection prevention and control measures (balancing loop B3). As a result, the rate of complications among HD patients increased. Although patients with complications receiving HD at public or private hospitals can be treated in the same hospital, patients in private HD clinics have to transfer to a hospital. High complication rates can therefore increase the number of transfers from private HD clinics to hospitals. Beyond increasing burden on hospitals, this reduces the number of clients in private HD clinics and increases competition for clients. Private HD centres can attract new patients by remunerating doctors referring patients to their HD centre. This fee (referred to as the doctor fee) is paid per patient per session. In the private centres surveyed, 3 out of 4 paid a doctor fee, which varied between 150 and 250 THB per session.

> "ค่า *DF* เนียมันเกิดบึ้นเนืองจากว่าโรงพยาบาลหรือเอกชนเนียไปออกแบบเองเพือทีจะดึงคนไข้แล้วก็อาจจะให้หมอโรคไตชักจูงให้หมอโรคไตส่งคนไข้เนียไปให้เขา นีกออกไหมครั้บ ส่งคนไข้ไปให้เขาถ้ายิงส่งมาเขาก็จะมีค่าตอบแทนกลับไปของหน่วยบริการนะ"
> *"The DF [doctor fee] was designed by hospitals and private companies to attract patients and to persuade nephrologists to refer patients to them. Do you understand? If you refer patients to them, the more patients you send, the more compensation you will receive from the HD centre."*
> *Nephrologist 1 interview*

Increased competition for HD patients can raise the doctor fee, increasing the financial benefit for doctors to recommend HD to their patients (or even to initiate HD prematurely), further increasing number of new HD patients and maintaining demand to increase HD supply (reinforcing loop R3). This is an example of *setting the wrong goal archetype*, in which the incentives in the system lead to agents following a goal that is not aligned with the broader health system objectives.

The final coping mechanism in this section concerns vascular access, which is required before patients can initiate HD. The surge in HD patients meant that there were long waiting times for vascular access. Many doctors therefore initiated patients on HD with temporary access (balancing loop B4). Although this temporarily relieved pressure on vascular access services, it is another example of the *fixes that fail archetype* (a special case of *out-of-control archetype*), in which a delayed reinforcing loop unintentionally exacerbates the problem, as HD patients with temporary access are more likely to need multiple vascular access operations, leading to a growth in demand for vascular access services over time (reinforcing loop R4).

> "อย่างเช่นเส้นเลือดอย่างเช่นตรงอะไรอย่างเงียมันก็ไม่ทันครับมันก็ไม่ทันเพราะมีการ *shift* พอสมควรเลยก็ต้องไปใช้เส้นเลือดชั่วคราวเยอะบึ้น"
> *"For example, things like blood vessels are not ready in time. It's not in time and because there's quite a lot of shifting, we have to use more temporary vessels."*
> *Nephrologist 1 interview*

HD patients with temporary access have a higher rate of complications [48], leading to a net increase in the average doctor fee, due to previously described mechanisms (reinforcing loop R5).

> "คนไข้ต้องไปใช้เส้นเลือดชั่วคราวนะครับซึงมันมีเสียงมากเลย เสียงต่อการติดเชือ"
> *"The patient has to use temporary blood vessels, which are very risky and risk infection."*
> *Nephrologist 1 interview*

Table 4 Summary of problem archetypes and potential solutions (see text for details)

#	Problem	Archetype	Loops	Potential solutions	Solution loop(s)
1	Short-term fix to overcome bottlenecks in registration of private HD centres lowers quality and increases demand	Fixes that fail (out of control)	B1, R1, R6	**S1:** Pre-authorisation of new HD patients according to supply availability	B1a
		Drifting goal (relative control); Shifting the burden (out of control)	B1, B2, R2	**S2a:** Key performance indicators for regulatory capacity based on availability and competence of staff	B2a
2	Payment mechanism incentivises volume, not quality, of HD sessions	Seeking the wrong goal (out of control)	B3, R3	**S3a:** Payment per HD patient based on quality indicators	B3a, B3b
3	Short-term fix to address bottlenecks in vascular access exacerbates demand	Fixes that fail (out of control)	B4, R4, R5	**S1:** Pre-authorisation of new HD patients according to supply availability **S3a:** Payment per HD patient based on quality indicators	B4a, B4b
4	System response to address HD nurse deficit amplifies HD demand	Out of control	B8, R9	**S4a:** KPI for HD nurse to patient ratio	B9a
5	Short-term response to HD nurse deficit increases HD demand	Out of control	B6, R8	**S3a:** Payment per HD patient based on quality indicators	B8a
6	Short-term fixes for HD nurse deficit distract from investment in HD nurse training and exacerbate the problem over time	Drifting goals (relative control)	B6, B7	**S4a:** KPI for HD nurse to patient ratio	B7a
		Shifting the burden (out of control)	B6, B7, R7	**S5a:** Enforceable regulations for HD nurses (patients per nurse and hours per week)	B6a
7	High quality of PD services reduces perceived need for investment in PD, limiting future growth of PD	Growth and underinvestment (underachievement)	R10, B9, B10	**S6:** Proactive plan for investment in PD capacity relative to projected demand	R9a
8	Growth of HD occurs at the expense of PD	Success to the successful (relative achievement)	R9, R10	**S7:** External regulation of patient eligibility for PD/HD, via pre-authorisation	R10a

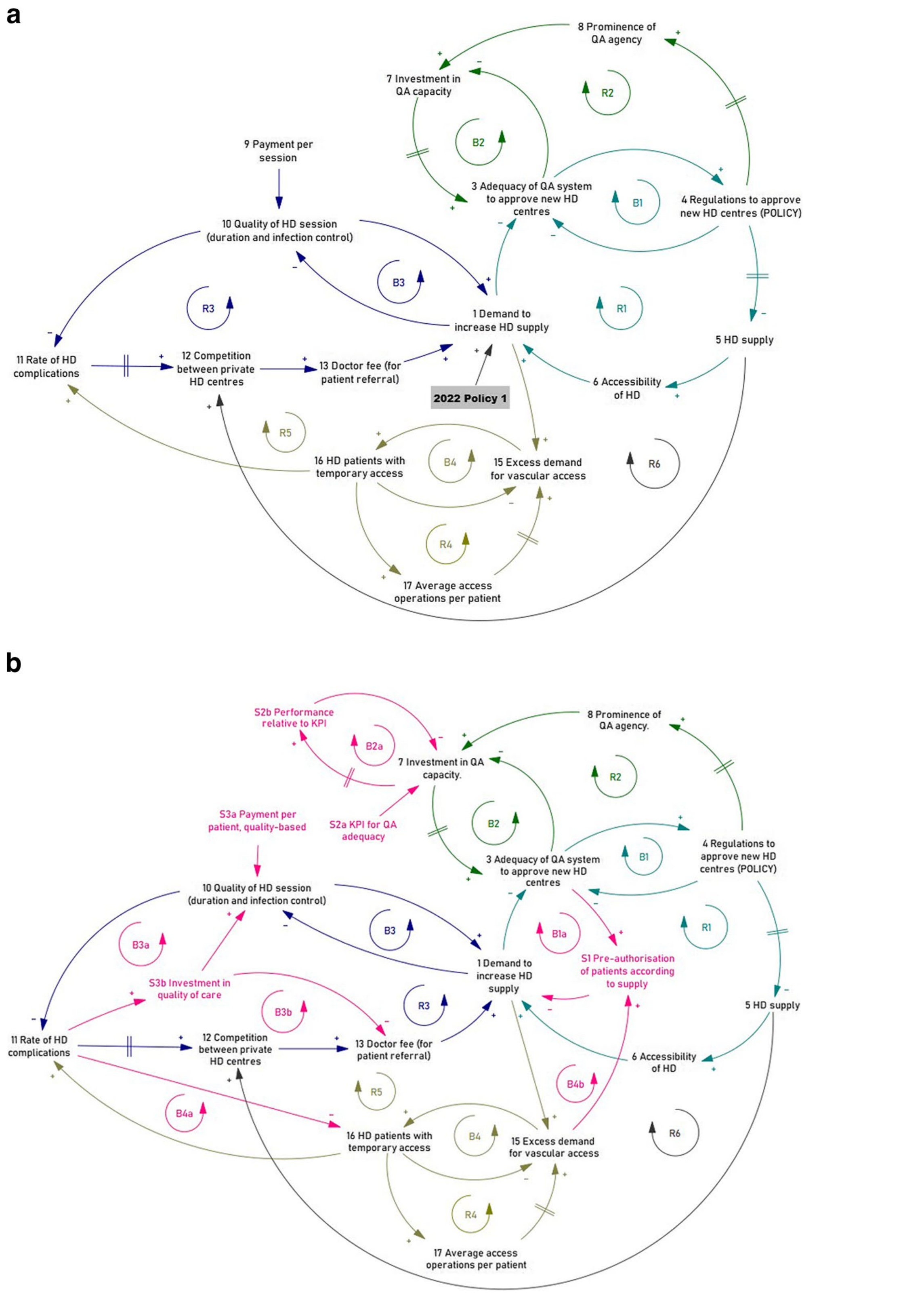


Fig. 1 **a** Dynamics causing shifts in quality of HD service provision caused by short-term coping mechanisms to deal with the surge in HD demand. **b** Potential solutions (in pink) to address the problems in **a**, based on generic solutions for out-of-control and relative control archetypes. HD—haemodialysis, KPI—key performance indicator, QA—quality assurance

Policies to ensure adequate supply while maintaining quality of care

Our analysis of system archetypes identified the following policy interventions: (1) pre-authorisation of new HD patients that accounts for availability of vascular access and HD services, (2) key performance indicators (KPI) related to number and competence of QA staff in relation to number of HD centres, and (3) changing the payment mechanism from fee per service to quality-based payments per patient. Figure 1b depicts the potential impact of these policies on the causal loop diagram.

A pre-authorisation system would require each patient to be approved by an oversight board at the regional level before they are able to access dialysis services. A similar system had been in place prior to the 2022 policy change. However, unlike the 2008–2022 policy, the pre-authorisation system would allow patients who prefer HD to access HD, provided that (1) timing to initiate HD is appropriate given the patient's kidney function, (2) the patient would not have better quality of life with another treatment, and (3) there is available HD supply. In the context of constrained HD supply, patients requesting HD who are not contraindicated would be required to start dialysis on PD. This solution aims to reduce induced demand for HD, including premature HD initiation, by replacing reinforcing loops R1/R6 and R5 with balancing loops B1a and B4b respectively. In balancing loop B1a, pre-authorisation phases the increase in HD patients at a rate that is constant with regulatory approval of new HD centres. In balancing loop B4b, excess demand for vascular access beyond system capacity is similarly moderated. This solution had already been proposed by the policy working group prior to our analysis.

The intention of a key performance indicator for QA staff would be to set a goal (for either the Ministry of Public Health or NHSO) that maintains investment into the QA system independent of measures to relax/heighten regulations. Such a measure aims to guard against a loss of capacity and maintain perceived importance of QA, by triggering investment when capacity is insufficient (balancing loop B2a).

Changing the payment mechanism from fee per session to patient-level payments contingent upon quality indicators aims to better align goals of service providers with those of the health system. Instead of increasing number of HD sessions, the emphasis is shifted to improving quality of patient outcomes. Reinforcing loop R3 is closed by balancing loops B3a and B3b, since higher complication rates trigger measures to improve quality of care (balancing loop B3a). This in turn reduces the funding available to pay for the doctor fee (balancing loop B3b). Patients with temporary access are expected to decrease also, in an effort to reduce complications (balancing loop B4a).

Mechanisms to address HD nurse shortages compromised quality of care and placed increased pressure on the HD nurse workforce

One of the factors counterbalancing the increase in HD supply is the availability of HD nurses, which acts as a limit to HD growth (loops R1/B5). As shown in Fig. 2a, the number of HD nurses can be increased through additional training, according to annual quotas determined by the Nursing Council. Short-term responses to overcome nurse shortages temporarily relieved system pressure, but compounded deficit of HD nurses in the long term, either by increasing demand for HD (*out-of-control archetypes* B8/R9 and B6/R8) or by decreasing number of HD nurses (*out-of-control archetype* B6/R7 and *relative control archetype* B6/B7).

In the current system, HD nurses have opportunities for career progression and recognition that are not available to PD nurses. There is therefore an ongoing transition of PD nurses to HD, which tends to be the more experienced nurses.

> *"Career pathway* ผลตอบแทนพิเศษ แรงจูงใจ ไม่มีให้พยาบาล *PD"*
> *"PD nurses do not have a career pathway, special compensation, or incentives."*
> *Nephrologist 1, workshop on 9th July 2024*
> *"Mindset* คนไทยให้บองบวัญพยาบาลไตเทียมเยอะ มี *social recognition"*
> *"It is in the mindset of Thai people to give lots of gifts to haemodialysis nurses. They have social recognition."*
> *Nephrologist 2, workshop on 9th July 2024*

With the sharp increase in HD nurse deficit following the 2022 policy change, one of the system responses was an increase in the rate of PD nurses transitioning to HD (balancing loop B8), which had implications for patient decisions between PD and HD (reinforcing loop R9). One of the main factors influencing patient decisions between PD and HD is perceived risk of infection on PD:

> *"[The three patient representatives] mentioned that they may not fully understand the concept of quality or survival outcomes, but they focus on the side effects and complications of dialysis, such as infections [...] Complications seem to be one of the main factors that concern some patients."*
> *Observations of patient inputs, workshop on 9th July 2024*

Although there are complications for HD too, the symptoms are often difficult to attribute directly to HD (for example, sepsis or cardiovascular disease), whereas the cause of peritonitis and other PD complications is less ambiguous.

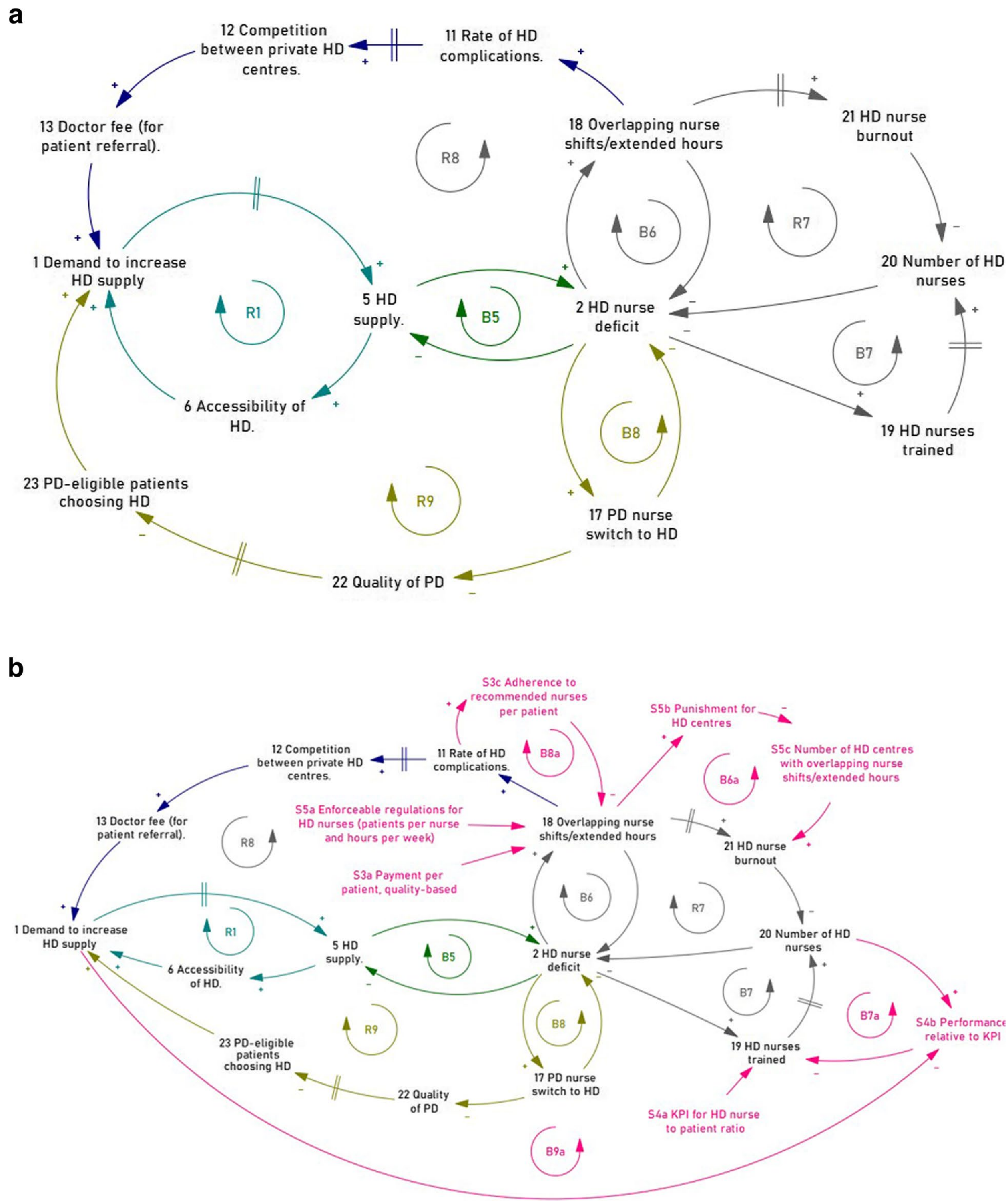


Fig. 2 **a** Dynamics affecting availability of HD nurses relative to demand. **b** Potential solutions (in pink) to address the problems in **a**, based on generic solutions for out-of-control and relative control archetypes. HD—haemodialysis, KPI—key performance indicator, PD—peritoneal dialysis

As more PD nurses switch to HD, risk of infection for PD patients increases due to the higher ratio of PD patients per nurse [49] and loss of experienced PD nurses.

> *"More experienced nurses tend to move to the private sector. The government setting has to train new, less experienced nurses, which may affect the quality of service."*
> *Observations of nurse inputs, workshop on 9th July 2024*

As a consequence, the proportion of PD-eligible patients choosing HD increases. This is another example of the *out-of-control archetype*, as the short-term counteracting measure exacerbates demand for HD nurses in the long term. Although PD nurses switching to HD is not an intentional action (which is a common feature of archetypes), we have nonetheless included it within the CLD, as it is influenced by the compensation and professional hierarchy within the Ministry of Public Health system.

The second mechanism to control the deficit in HD nurses was implemented by HD centres. HD nurse training takes 4–6 months (or longer for specialised HD nurses), represented by the delay in balancing loop B7. Many centres therefore implemented short-term measures to address workforce shortages (balancing loop B6): more HD nurses worked overtime or extended their hours to cover more shifts and some private HD centres registered the same nurse in two centres with overlapping shift times. As a result, more HD nurses had high workload, experienced burnout, and left to other professions (reinforcing loop R7).

> *"The increase in salary is not due to the amount of money but because of the increased workload (number of sessions and patients). This causes the number of nurses to decrease because it affects their quality of life."*
> *Observations from public sector nurse input, workshop on 9th July 2024*

Short-term coping mechanisms not only distracted away from HD nurse training programmes (*relative control archetype*, B6/B7), but also reduced training programme impact, as HD nurse turnover had increased (*out-of-control archetype*, B6/R7). Quality of HD services also decreased. Similar to reinforcing loop 3, this can lead to an increase in financial incentives for HD, exacerbating HD nurse shortages in the long term (reinforcing loop R8).

Policies to sustainably address shortages in HD nurse workforce

We identified the following potential solutions to the deficit in HD nurses, based on the system archetypes: (1) quality-based payments per patient as opposed to payment per HD session, (2) setting a KPI for the Ministry of Public Health or the Nursing Council related to number of registered HD nurses relative to HD patients, and (3) enforceable regulations defining maximum HD patients and/or hours per HD nurse. The modified CLD with solution archetypes is shown in Fig. 2b.

Quality-based payments per patient aim to change the incentive for healthcare providers towards increasing patient quality of life. This closes reinforcing loop R8, as it is expected that HD centres are more likely to adhere to the recommended number of nurses per patient, in order to manage complication rates (balancing loop B8a).

Setting a KPI for the HD nurse to patient ratio aims to fix number of nurses trained according to actual need (nurse to patient ratio) and not perceived need, which may be obscured by temporary coping mechanisms. This provides a holistic solution to the *relative control archetype* in loops B6, B7, and B8, as the fundamental solution to HD nurse shortages (training) is moderated relative to KPI performance (B7a and B9). This KPI is not at the level of individual centres (who face severe nurse shortages) but at the national level. It would require, however, regular censoring of HD nurses in active employment, which does not currently exist, and measures to address regional health workforce inequities.

Enforceable regulations around maximum workload for HD nurses (in terms of patients and/or hours per week) aim to reduce burnout of HD nurses. The structure of loop R7 is changed to a balancing loop (B6a), controlling HD nurse burnout by punishing HD centres exceeding the permissible weekly HD nurse workload.

Underinvestment in PD capacity coupled with increasing investment in HD has led to a decline in PD uptake

In contrast to the HD system, the system for PD is characterised by archetypes that limit its growth (Fig. 3a).

In the *growth and underinvestment archetype* (special case of the *underachievement archetype*), an initial improvement in performance is limited by a resource constraint, and the resulting drop in performance discourages further investment [19]. In the case of PD, as number of PD patients increases, so does experience and size of PD centres, improving the quality of PD services [49, 50] (reinforcing loop R10). However, quality is also dependent on the availability of PD nurses [49, 50], which decreases with more PD patients (balancing loop B9). Expansion of PD capacity (including number of PD

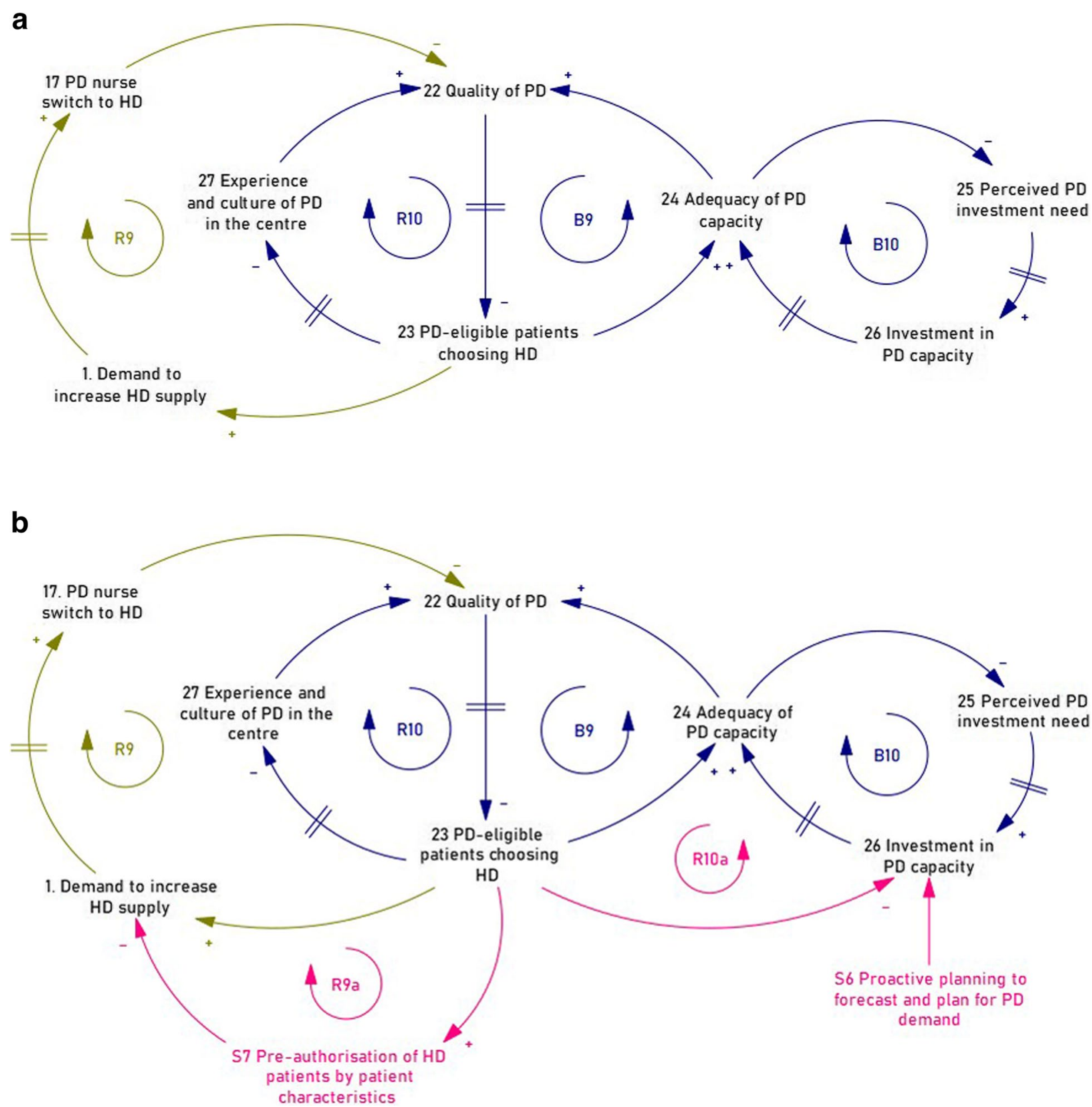


Fig. 3 **a** Dynamics affecting availability and quality of PD services. **b** Potential solutions (in pink) to address the problems in **a**, based on generic solutions for underachievement and relative achievement archetypes. HD—haemodialysis, PD—peritoneal dialysis

centres and PD nurses) is dependent on perceived investment need by hospital directors. There is a delay between perceived investment need, investment, and increase in capacity, due to the time to train nurses and open PD centres (balancing loop B10). As a result, increases in infection from lack of capacity can lead to fewer patients choosing PD, which disincentivises further PD investment.

"If the number of PD patients decreases, hospital directors may not perceive the importance of PD nurses and may not support their training." Observations from nephrologist input, workshop on 9th July 2024

The second archetype constraining growth of PD is the success to the successful, or *relative achievement* *archetype*. In reinforcing loop 9, an increase in PD nurses switching to HD led to fewer patients selecting PD. When combined with reinforcing loop R10, this leads to a loss in the experience and culture of PD in public hospitals providing PD services. The growth of HD is therefore achieved at the expense of the PD system.

Policies to maintain capacity for PD

The solution archetype for underachievement involves development of a proactive plan, and the solution archetype for relative achievement entails external regulation [19]. As shown in Fig. 3b, proactive planning to scale PD investment relative to projected PD demand addresses underinvestment in PD (reinforcing loop R10a), while an independent pre-authorisation system to approve patients initiating HD according to patient characteristics would maintain the number of patients selecting HD at a level that is sustainable for the system (reinforcing loop R9a).

Discussion

In this study, we applied systems thinking to understand the dynamics underlying demand and supply for KRT services following the 2022 policy in Thailand, which lifted restrictions to certain services but also unintentionally increased registered patients, expenditures, and patient mortality. Our analysis suggests that these unintended consequences arose from reactive actions that did not account for long-term consequences. Underinvestment in PD from demand-based (as opposed to proactive) planning failed to capitalise on prior gains in expertise and quality of PD services. For HD, a series of short-term measures to overcome supply constraints had the unintended consequence of increasing long-term demand, degrading the quality of both HD and PD services.

By applying generic solution archetypes, we identified a series of measures to balance demand for services with system capacity: (1) changing payment mechanisms from fee-per-service to quality-based fee-per-patient; (2) putting in place an external regulatory mechanism (pre-authorisation) to approve dialysis initiation according to patient profile and available supply; (3) using data from the regulatory mechanism to proactively project demand and invest in future capacity for KRT services and quality assurance mechanisms; (4) introducing key performance indicators linked to adequacy of the nurse workforce and quality assurance bodies; and (5) introducing and enforcing regulations around workload of HD nurses. Overall, these measures seek to align incentives within the system with those of the health sector, as well as shifting from reliance on market forces to proactive planning and external regulation.

Our findings reflect recommendations from a strategic health workforce planning group model building exercise in Thailand, which found that investment in hospitals and measures to increase the hospital workforce not only amplified shortages in healthcare staff and investment at lower levels of the healthcare system, but also further amplified demand for hospital services [32]. Through quantitative system dynamics modelling, study authors similarly propose a shift away from reactive measures aimed at increasing system capacity towards proactive planning and system re-design [32].

Since our study was exploratory in nature, we focussed on policy interventions with the highest potential to improve quality and financial sustainability, but success will depend to a large extent on how each policy is implemented. For example, the success of quality-based provider payments can depend on whether the selected KPIs fully capture quality from a clinical and patient perspective, timeliness of provider payments, and mechanisms to account for social determinants of health in the populations served by different providers [51–53]. To address this, we propose that the CLD continue to be updated throughout policy planning and implementation to facilitate learning. CLDs are best used in policy when iteratively updated to integrate new information and inform programme design as new insights emerge [26]. The NHSO Board has established a permanent policy working group on kidney disease, tasked with setting up a monitoring system and conducting periodic review of data to propose refinements to the policy. The CLD could support this working group to prioritise research and to refine the policy as further knowledge emerges. Beyond improving KRT policy roll-out, this would have the additional benefit of building capacity for systems thinking within NHSO policy processes, supporting future institutionalisation of evidence-based processes for policies related access and delivery of services, which will need to account for system complexity.

A strength of our study is that we applied system archetypes to understand and narrate the complexity of the CLD, which has been underutilised in similar studies (for example [14, 15, 54–57]). However, it is possible that the reliance on system archetypes constrained the solution space of our proposed policy interventions. A policy proposed by the policy working group that was not identified by system archetypes approach was abolishing financial incentives for doctors. Instead, our proposed solutions to change payment mechanism (solution loop S3a) and external regulation (solution loops S1 and S7) indirectly affect the same issue. It is unclear whether the solutions identified by archetypes may be more robust (stakeholders mentioned, for example, that more aggressive marketing or gifts to doctors could replace the doctor fee, if abolished), or whether it would have been prudent to take a more comprehensive approach to identify solutions beyond focussing on system archetypes. Similarly, the working group proposed patient education by multi-disciplinary teams and protocols to evaluate new patients for comprehensive conservative care, as effective approaches that had reduced demand for HD in other countries [43, 44]. Neither of these policies changed the structure of loops in the CLD and were therefore not proposed by our analysis. We argue that they may be an example of interventions that have limited transferability across different health system contexts—which systems thinking methods intend to explore—but verifying this hypothesis is important for evaluating the applicability of general solution archetypes. We plan to explore both of these questions further through system dynamic modelling of interventions (both those proposed in this paper and others nominated by stakeholders) and through longer-term monitoring of the final policy change. If solutions outside of generic archetype solutions do appear to offer important benefits, we would propose coupling archetype-based solutions with other established techniques to identify policy interventions from CLDs from system-wide leverage points. These techniques include disrupting or strengthening individual loops by modifying loop structure and targeting high-impact nodes (for examples see [13, 58]), as opposed to "closing" archetypes.

Other limitations of our study primarily arose due to time and resource constraints, which is often a feature of studies conducted to directly inform policy [59, 60]. The CLD was developed by a single researcher, which could have led to cognitive bias in interpreting relevant information in causal links. We believe that this limitation was overcome by review from other researchers who were conducting concurrent studies aiming to understand factors influencing the rise in number and death rate of patients on HD, with access to official databases (Teerawattananon Y, Chavarina KK, Phannajit J, et al: Nature medicine commission on dialysis policy in low- and middle-income countries: from policy to pivotal impact: Thailand's dialysis reform journey and its unexpected consequences, submitted), as well as from critique during a stakeholder workshop. However, the workshop was only half a day, which was sufficient for gaining feedback and input from all stakeholders, but not for coming to a shared understanding across the different groups. More importantly, we did not have the opportunity to present back proposed solutions to workshop participants, which would have identified whether our view of the system led us to ignore potential consequences, including range of possible stakeholder responses [57]. We did, however, follow-up regularly with the secretariat coordinating all research projects for the 2024 KRT policy for their review of interim drafts, as secretariat members had a broad knowledge of different stakeholder perspectives and the body of research on KRT in Thailand. Finally, although CLDs are typically developed through open discussion to improve joint learning, certain information in the CLD is based on an anonymous survey with a small sample size. Yet since we were requesting sensitive information, we felt this was necessary, as use of anonymous surveys has been found to improve validity of participant answers [61].

Incorporation of this analysis within official policy processes of the NHSO improved the legitimacy of the study, as evidenced by a high level of engagement from all stakeholders approached throughout the analysis, and also allowed us to leverage data and insights from other commissioned research studies. Perhaps unsurprisingly for a new approach being introduced into established policy institutions, stakeholder understanding of the CLD itself was low, and we relied heavily on storytelling to receive their feedback and input. Applying system archetypes did, however, identify additional policy solutions and highlighted which of a long list of proposed policy interventions were most likely to be successful in the Thai context.

To our knowledge, this is the first study to illustrate the use of causal loop diagrams within established health priority-setting policy mechanisms. Beyond this specific policy, a major implication of this research is that more detailed planning, multi-stakeholder engagement, and consideration of potential consequences are required before changing policies around healthcare service access and delivery. Due to complexity of healthcare systems, even small changes could have potentially vast consequences. Although policy institutions that evaluate the impact of technology introduction decisions are well-developed in countries such as Thailand [62], mechanisms to evaluate access and delivery of services have yet to be defined. In setting up such mechanisms, it will be important to consider when existing methods and processes can be adapted and when introduction of approaches such as systems thinking is warranted, as well as the level of capacity building required. Given limited resources and technical expertise in many settings, further research into this area could help to make the best use of priority-setting resources.

Conclusions

We used causal loop diagrams and system archetypes to understand the complexity driving supply and demand of HD and PD services under a government-funded health insurance scheme. We found that short-term fixes to cope with high demand for HD were unintentionally increasing future demand and decreasing service quality, while underinvestment in PD had limited the impact of achievements in building PD capacity and expertise. Overall, our results emphasise the importance of aligning incentives with health system goals, undertaking proactive planning based on forecasted demand, and putting in place regulatory mechanisms to balance supply and demand according to available health sector resources.

Abbreviations

CCC	Comprehensive conservative care
CLD	Causal loop diagram
HD	Haemodialysis
KPI	Key performance indicator
KRT	Kidney replacement therapy
NHSO	National health security office
PD	Peritoneal dialysis
QA	Quality assurance
THB	Thai Baht (currency)
UCS	Universal coverage scheme (Thailand)

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12916-025-04054-6.

Additional file 1: Tables S1-S3, Figure S1. Table S1 - Profile of interviewees. Table S2 - Profile of workshop participants, facilitators, and observers. Table S3 - Questions included in the survey to dialysis centre directors. Figure S1 - Interim causal loop diagram presented to workshop participants.

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Authors' contributions
Conceptualisation and methodology: SB, LKNN; data curation: YT, JP, JS; investigation: SB, YT, NY, JP, JS; formal analysis: SB; validation: YT, NY, JP, JS; writing – original draft: SB; writing – reviewing and editing: YT, NY, KKC, LKNN; supervision: YT, LKNN; project administration: KKC, JS; funding acquisition: YT, KKC, JS. All authors read and approved the final manuscript.

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Data availability
The datasets generated and/or analysed during the current study are not publicly available for ethical reasons (data comes from interviews, workshop observations, and anonymous surveys).

Declarations

Ethics approval and consent to participate
The Institute for the Development of Human Research Protections (IHRP) Thailand Ethics Committee approved the sub-study data collection process on February 22nd, 2024 (COA No. IHRP2024025; IHRP No.002–2567).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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