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Mapping the 'prevalence' and frugal characteristics of healthcare innovations in South Africa

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ABSTRACT

Background Despite postdemocracy reforms, South Africa's healthcare system remains fragmented and under-resourced, limiting equitable access. Although the National Health Insurance (NHI) promises to bridge some of these gaps, public sector health innovations remain poorly documented with siloed information across care levels, hindering a comprehensive understanding of system-wide responses to challenges.

Objective To identify, categorise and assess the prevalence and frugality of public sector healthcare innovations at multiple facility types across the country.

Design A cross-sectional study was conducted involving 142 participants drawn from 71 public healthcare facilities including primary healthcare (PHC) clinics, hospitals and pathology laboratories. At each facility, two participants independently evaluated their respective innovations using structured self-administered questionnaires to assess frugality on a 7-point Likert scale.

Analysis Innovations were classified into three categories including product, process and business model. The degree of frugality was assessed using a three-dimensional framework: accessibility, affordability and adaptability. Descriptive statistics was employed to summarise the data and χ^2 tests were conducted to examine associations and identify significant characteristics.

Results A total of 201 facility-innovation instances were recorded. Product innovations were most prevalent (n=78), followed by business model (n=69) and process innovations (n=54). Frugal innovations were found across all facility types, with PHC clinics and National Health Laboratory Service (NHLS) reporting the most innovations. In total, 57% of innovations were frugal. Widely diffused innovations included the Central Chronic Medicines Dispensing and Distribution, Point of Care Testing and Health Patient Registration System. Most (89%) innovations were push-driven.

Conclusions The study uncovered a widespread but under-reported ecosystem of frugal healthcare innovations addressing key public healthcare challenges. Insights can inform policy on embedding frugality to promote access and equity within the NHI framework.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Public-sector innovations in South Africa exist across levels of care, but their frugal characteristics remain largely undocumented.

WHAT THIS STUDY ADDS

⇒ This study provides the first large-scale mapping demonstrating that more than half of public health sector innovations have frugal characteristics and are widely distributed across primary healthcare, hospital and laboratory settings.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The findings highlight opportunities to institutionalise frugal innovation within NHI implementation, offering a structured approach to assess and scale cost-effective solutions; showing how adaptive, system-level innovations developed in resource-constrained settings may offer valuable lessons for even high-income countries facing cost and access pressures.

INTRODUCTION

There is a global shift towards Universal Health Coverage (UHC) to ensure equitable healthcare for all individuals without suffering financial hardship.[1] This aligns

with the 2030 Sustainable Development Goals, positioning UHC as a foundation for health systems strengthening.[1]

However, achieving UHC targets remains challenging in low-income and middle-income countries (LMICs), with persistent barriers such as skills shortages, inadequate funding and access inequalities in service delivery.[2] Consequently, healthcare innovations such as new care delivery models, health financing reforms and low-cost technologies are critical to advance UHC objectives in these contexts.[2] Countries such as Ghana and Rwanda have implemented innovative reforms such as National Health Insurance (NHI) to expand access and have promoted low-cost solutions such as Kangaroo Mother Care (KMC) to reduce newborn mortality and reusable malaria diagnostic tests.[2] Despite such successes, contextually, many LMICs struggle to achieve UHC due to systemic constraints.[2] The South African healthcare system grapples with similar constraints. Despite policy reforms since the 1994 democratic transition, the system remains fragmented, with persistent racial and spatial inequalities in accessing care.[3 4] The country remains among the most unequal globally by Gini coefficient.[5]

In this paper, our focus is on how existing innovations diffuse within the health system, rather than on their initial development. Consistent with previous work on diffusion theory,[6 7] understanding such a context can influence whether promising ideas do scale. For instance, Berwick (2003)[6] states 'in many health care organizations, no formal mechanisms exist for identifying changes that should be deployed, such as assigning responsibility for routine, high-level surveillance of key scientific journals or for attending key scientific meetings and reporting back reliably to the organization on ideas that should be spread' (p1973).

Within the South African system, healthcare is provided at national, provincial and local levels.[3 8] However, access is fragmented along public–private health sector, urban–rural and socioeconomic lines.[8 9] The public health sector serves approximately 84% of the population, largely low-income, while the private sector services the 16% funded through medical insurance.[8] Both sectors account for a roughly equal share of the national health expenditure, resulting in disproportional benefits for the private sector.[3 10] Inequalities extend to the workforce distribution between the two sectors.[8] Workforce challenges and limited resources in rural settings further exacerbate these inequalities.[3 11]

South Africa has responded to these challenges by adopting the NHI in May 2024, aligning with calls for UHC.[12] The NHI will become a single-payer system grounded on principles such as equity, access and affordability.[12] However, concerns remain about its affordability and sustainability.[13]

Understanding public sector innovations within these contexts is essential to appreciate how such systems adapt to structural challenges. This study forms part of a larger multiphase project, and the current paper reports on phase 1, which maps and characterises public sector innovations across four provinces, revealing insights into their prevalence and characteristics to inform policy and practice. At a theoretical level, the study seeks to explore the extent to which these innovations exhibit characteristics of frugal innovation (FI). FI has emerged as a promising approach to advance UHC, offering solutions that are affordable, accessible and adaptable to resource-limited environments.[14 15]

By applying the lens of FI, the drive towards UHC is contextually informed from the South African perspective.[14 15] Our intention is to link the contextual needs of this health system with the theoretical understanding of different types of innovations and to assess the prevalence and relevance of each type. In doing so, the analysis contributes to both scholarly debates and practical decision-making.

Contextual: the health sector innovative landscape in South Africa

The healthcare sector has adopted several innovations appropriate to its context.[16] In 2011, the National Department of Health initiated a 5-year NHI pilot as part of health systems strengthening at primary healthcare (PHC) clinic level, with various public healthcare innovations iterated.[3 16] See examples in online supplemental file 1.

While the success and challenges of some innovations have been evaluated,[16] a mapping exercise of the public health innovation landscape can be beneficial to improve access and equity. Since UHC reforms cover multiple care levels, investigating innovations across different levels of care offers valuable insights into their innovative journey.

Theoretical: FI

FI has gained global attention as a strategy to contain healthcare costs in resource-limited contexts.[17–19] Defined as '*means or ends, to do more with less, for the many*', FI is commonly understood in terms of its outcomes: *affordability*, *accessibility* and *adaptability* and delivered through different forms of innovation, including technological, social and institutional innovations.[14 15] The innovation may therefore achieve its outcomes through technologies (eg, devices or digital tools),[20] social arrangements (eg, community-based delivery models)[21] and institutional mechanisms (eg, new service or governance arrangements).[22] The distinction between ends (frugal outcomes) and means (how outcomes are achieved) provides an analytical lens for linking the study to prior literature and understanding how different types of innovation contribute to frugality across diverse health contexts. Originating in LMICs, FI has also gained traction in high-income countries (HICs).[15 23]

Table 1 Examples of healthcare frugal innovations by category

Category	Innovation	Innovative features	Documented or potential impact	Potential for cost reduction	References
Product innovation	Arbutus Drill Cover System	A repurposed standard hardware drill with a reusable sterile cover to create an affordable drill used in orthopaedic surgery. Originated in Malawi and Uganda, further developed in Canada and subsequently adopted in other HICs, exemplifying reverse innovation	Maintains clinical performance and safety standards comparable to conventional surgical drills and improves access to orthopaedic surgery in resource-constrained contexts	Up to 94% cost reduction compared with a conventional surgical drill	28 51
Process innovation	Kangaroo Mother Care	A low-cost technique using skin-to-skin contact between mother and infant to provide support for preterm babies, developed in Columbia in response to incubator shortages	Reduces neonatal mortality by up to 32%, lowers infection and improves growth outcomes, particularly in LMICs	Widely regarded as a low-cost alternative to incubator care, with studies showing lower out-of-pocket costs (US$20.0 vs US$25.6 per infant), and up to US$8.5 potential savings per infant when seeking care, including reduced risk of household impoverishment	27 45 52 53
Business model innovation	Narayana Health Cardiac Surgery	A high-volume 'assembly line' cardiac surgery that employs task shifting, cross-subsidisation and economies of scale to deliver care affordably. Inspired in India by Mother Teresa's physician, Devi Shetty, the innovation expands access to affordable, high-volume cardiac surgery	Comparable or improved surgical outcomes, expanding access by treating a third of its patients without charge	Average cardiac surgery costs less than 10% of those in HICs	19 25 26

HICs, high-income countries; LMICs, low-income and middle-income countries.

FIs are commonly classified into *product*, *process* and *business model* innovations, identified using the three-dimensions of *affordability*, *accessibility* and *adaptability*.[14 15] *Affordability* addresses the perceived cost-saving, compared with existing solutions, while *accessibility* evaluates whether the innovation reached fewer, same or more people than the previous solution and *adaptability* assesses innovation's performance relative to existing solutions.[14 15 24]

Several frameworks have been proposed to classify FI, many of which primarily focus on product and/or service innovations.[20 23] However, our study employs the three-dimensional framework because it includes process and business model innovations, alongside product innovations, making it particularly appropriate for analysing innovations within the public sector health systems. Within this framework, *product innovations* refer to tools or devices supporting healthcare delivery; *process innovations* involve new methods or workflows that enhance service delivery; and *business model innovations* reorganise or finance services more efficiently, such as payment systems or partnerships.[25] Although associated with LMICs, FIs are by no means inferior, and can maintain or improve quality at the same or lower cost.[26] This has influenced their adoption in HICs, a concept called reverse-innovation.[26–28] Table 1 provides examples of product, process and business model FIs reported in literature, highlighting their potential cost savings and impact on clinical outcomes.

Most FIs have been reported in healthcare,[29] given its complexity and need to innovatively address multi-dimensional challenges. Despite cost-saving advantages and alignment with South Africa's public health needs, documentation of FIs remains limited.[19 23]

Against this background, this study maps and classifies public sector healthcare innovations in South Africa, assessing their frugal characteristics and providing empirical evidence that informs health system policy and innovation scholarship.

METHODS

Study design

This cross-sectional study employed an exploratory and descriptive mixed-methods design comprising both quantitative and qualitative approaches (online supplemental figure 1). Only phase 1 quantitative findings are reported in this paper because this is a multiphase research project. In phase 1, we conducted a survey to map and understand who is innovating and what types of innovations are being proposed in the South African health system. In phase 2, we evaluate these innovations against the NHI principles to determine alignment with national priorities. In phase 3, we qualitatively analyse the barriers and facilitators to innovating in South Africa. In this paper, we divulge the findings of phase 1 to focus on understanding the prevalence of local innovations and their frugal characteristics. This approach is consistent with recent guidance on the need to collect data from different contexts for evidence-based insights on innovative practices and technologies, since conducting such rigorous evaluations empowers healthcare decision-makers to make informed decisions on which innovations to continue, scale or modify.[30]

Table 2 Data collection sites across provinces

Facility type	Gauteng	Mpumalanga	Free State	Northern Cape	Total per facility type	National total (n)	Proportion per facility type
PHC clinics/CHCs	12	7	7	5	31	3841	0.8%
NHLS laboratories	12	4	2	3	21	233	9.0%
District hospitals	2	4	5	3	14	260	5.4%
Central hospitals	3	0	1	0	4*	10	40%
Total	29	15	15	11	71		

*Represents 40% of the country's central hospitals (n=4), which includes five HODs (one site provided two HODs). Selection includes one site in KwaZulu-Natal. Mpumalanga and Northern Cape have no central hospitals.
CHCs, community health centres; HODs, Heads of Department; NHLS, National Health Laboratory Service; PHC, primary healthcare.

Contextual factors

South Africa has an estimated population of approximately 63 million people as of mid-2024, with an urbanisation level of 69.3%.[31] Its health system operates through a multiprovider arrangement in which approximately 16% of the population is covered by private medical insurance, while the remaining 84%–85% rely primarily on publicly funded health services; out-of-pocket expenditure accounts for approximately 0.6% of gross domestic product (GDP).[3 10] The public health system is divided into 9 provinces and 52 health districts, with PHC serving as the cornerstone of the health system.[3] There are approximately 260 district hospitals, 10 central hospitals and 3841 PHCs and community health centres (CHCs).[32] These are supported by a national network of 233 public pathology services through the National Health Laboratory Service (NHLS), serving over 80% of the population.

Study setting

Data were collected from 31 PHC clinics (both 8-hour and 24-hour CHCs), 21 NHLS laboratories, 14 district and 4 central hospitals in South Africa between June 2024 and February 2025 (table 2). The study sites reflected a mix of urban and rural settings. Each laboratory in central hospitals had a dedicated manager for each discipline and was thus treated as a distinct site. Departments within central hospitals were also treated as separate sites.

Study sample and data collection

Given South Africa's geographic size, dispersed population and diverse range of health providers, a purposive snowball sampling strategy was employed. This approach was selected to align with the projects' available resources and to increase the likelihood of identifying innovations most relevant to the NHI objectives of improving efficiency and effectiveness. The intention was not to achieve statistical representativeness but rather to ensure the relevance and richness of cases for mapping and characterising public-sector innovations.

While the study uses the term 'prevalence' to describe observed FIs across the study sites, this does not imply statistically representative national estimates. Measuring the prevalence of often undocumented phenomena such as FIs can present methodological challenges, particularly in LMIC contexts with resource constraints and institutional voids that undermine accurate collection. Similar challenges have been noted in other fields, such as medicine quality sampling studies where prevalence is used cautiously in LMICs with caveats that the data may be imperfect but still provides the best available evidence for policy-relevant insights.[33 34]

Innovations were further classified by origin, distinguishing between push innovations (externally initiated) or pull innovations (locally developed in response to context-specific challenges). This distinction provides valuable insights into the ways innovations emerge, diffuse and are sustained within the public health system.

District managers overseeing PHC clinics and district hospitals and NHLS laboratory business managers identified relevant innovations and referred us to facilities implementing them. Data collection was conducted in two phases: identifying innovations followed by questionnaires at facilities.

At each facility, managers selected one product, process and business model innovation with the most frugal potential. The managers and one nominated frontline staff member (ie, doctor, nurse, medical technologist, other allied professionals) completed a self-administered questionnaire (SAQ) on Research Electronic Data Capture (REDCap), an online electronic survey system[35] (online supplemental file 2). The SAQ, adapted from previous FI in healthcare studies,[15 24] was completed by 142 participants (71 facility managers and 71 frontline staff) and took approximately 1 hour (table 3).

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline was followed in drafting this paper,[36] alongside the STROBE reporting checklist,[37] included in online supplemental file 3.

Patient and public involvement

Patients were not involved in setting the research agenda. However, the inclusion of frontline health

Table 3 Breakdown of participants across provinces

Participant type	Gauteng	Mpumalanga	Free State	Northern Cape	KwaZulu-Natal	Total
Facility managers						
Clinic managers	12	7	9	6	0	34
Laboratory managers	12	4	2	3	0	21
District hospital CEOs	2	4	3	2	0	11
Central hospital HODs	3	0	1	0	1	5
Subtotal for facility managers	29	15	15	11	1	71
Frontline staff						
Nurses	13	9	12	6	0	40
Doctors	3	2	0	2	0	7
Medical technologists	8	4	2	3	0	17
Allied professionals (physiotherapists)	1	0	1	0	1	3
Allied professionals (laboratory clerks)	4	0	0	0	0	4
Subtotal for frontline staff	29	15	15	11	1	71
Total participants	58	30	30	22	1	142

CEOs, Chief Executive Officers; HODs, Heads of Department.

workers involved in service delivery enhanced the diversity of perspectives in the study as well as the contextual relevance of the findings.

Data analysis

REDCap data were exported into Excel and analysed using Stata 17 software. A unit of analysis was defined as a unique facility-innovation instance and assigned to either product, process or business model innovation category.

Each innovation was independently rated by two participants using a 7-point Likert scale. Frugality was assessed using the three dimensions of *accessibility*, *adaptability* and *affordability*.[15 24 25] The assessment of each dimension was contextual, with participants asked to evaluate each innovation relative to the previous solution used in their setting. The scale interpretation depended on the dimension assessed:

1. Affordability: score of 1 indicated *strong disagreement* (ie, innovation not affordable) and 7 indicated *strong agreement* (ie, innovation highly affordable).
2. Accessibility: score of 1 indicated that the innovation was available to *far fewer people* and 7 indicated availability to *many more people*.
3. Adaptability: score of 1 indicated *worse performance* in adaptation to different contexts and 7 indicated adaptation resulting in *much better performance*.

For each item, individual scores from both participants were averaged to arrive at a single aggregated score per facility-innovation instance. One central hospital was excluded from the analysis due to missing ratings from one of the two raters. Further details on sub-items can be found in the online supplemental file 2. Inter-rater reliability was assessed using Cohen's kappa.

An innovation was classified as frugal and assigned a binary score of 1 if all three dimensions met the minimum threshold (ie, ≥5 for affordability and ≥4 for adaptability and accessibility). A score of 5–7 for affordability indicated slight to strong agreement. A score of 4 for adaptability and accessibility indicated that the solution performed either '*as good as*' or was available to '*about the same people*' when compared with the previous solution. Innovations that could not meet the thresholds for all dimensions (non-frugal) were assigned a score of 0.

Descriptive statistics were used to determine the prevalence and frequencies of innovations, including their frugality. Data were analysed for statistical associations (ie, χ^2) between innovation characteristics and facility types. A 5% significance threshold was used.

RESULTS

We identified 201 facility-innovation instances across four provinces spanning PHC clinics, district hospitals, central hospitals and NHLS laboratories. In total, 57% of these innovations met the frugality criteria, demonstrating alignment with the dimensions of affordability, accessibility and adaptability. In addition, we report detailed statistical assessments, including inter-rater reliability, and present analyses by facility type, geographic location and innovation origin.

Cohen's kappa

Mixed Cohen's Kappa scores were observed, reflecting meaningful diversity in professional perspectives, which was expected when enrolling participants of distinct roles to take SAQs. See online supplemental file 3 for Kappa scores and analysis.

Prevalence and frugality of innovations

A total of 78 *product*, 54 *process* and 69 *business model* innovations were identified at different facilities (see online supplemental files 5–7). Frugality was confirmed in 52.6% of *product innovations* (n=41), 63.0% of *process innovations* (n=34) and 58.0% of *business model* innovations (n=40) based on the frugality thresholds set (online supplemental files

Table 4 Distribution of FI categories within facility types (total 115 innovations)*

Facility type	Product innovation n (%)	Process innovation n (%)	Business model innovation n (%)	Total FIs per facility
PHC	14 (29.2%)	11 (22.9%)	23 (47.9%)	48
District hospital	7 (31.8%)	8 (36.4%)	7 (31.8%)	22
Central hospital	3 (30%)	2 (20%)	5 (50%)	10
NHLS	17 (48.6%)	13 (37.1%)	5 (14.3%)	35
P value	0.042	0.356	0.618	

*Percentages are row percentages (within facility type).
FIs, frugal innovations; NHLS, National Health Laboratory Service; PHC, primary healthcare.

8 and 9). The accessibility dimension consistently received the highest rating (over 90% across all categories). This was followed by affordability (>80%) and adaptability (>60%), indicating that participants widely perceived the innovations as accessible, cost-effective and appropriate to the context.

Distribution of innovation categories by facility type

The χ^2 revealed a statistically significant association between product FIs and facility types (p=0.042). No statistically significant associations were observed between facility types and process (p=0.36) or business model innovations (p=0.62) (table 4).

PHC clinics reported more business models (47.9%). District hospitals more frequently reported process innovations (36.4%), while central hospitals predominantly reported business model innovations (50%) and NHLS frequently reported product innovations (48.6%).

Innovation distribution by geographic location

The product (p=0.004) and business model FIs (p=0.031) had a statistically significant association between urban and rural facilities (table 5), while no significant association was observed for process innovations (p=0.178).

Urban facilities had a marginally higher distribution of product innovations (35.6%) and rural facilities adopted more business model innovations (46.4%).

Diffusion of innovations across facilities

The cross-sectional mapping of the prevalence of innovations suggests there is a broad diffusion of innovations (frugal and non-frugal) across the public healthcare system (table 6). See online supplemental files 10–12 for a detailed account of how many innovations and where innovations were found.

Product innovations

The most adopted innovations were blood gas point-of-care testing (POCT) and Health Patient Registration System (HPRS), each reported at 10 facilities. Other commonly diffused product innovations were MomConnect (n=6), a mobile phone-based solution providing maternal health education and antenatal care support and Webview (n=5), a laboratory information system that allows digital transmission of test results.

Process innovations

These were dominated by laboratory automation (n=8), an integrated system streamlining laboratory processes to improve testing capacity, electronic laboratory (e-Lab, n=5), digitising laboratory sample tracking and workflow and electronic gatekeeping (n=5), which reduces wastage by managing test requests to improve efficiency. Other innovations included Tracking and Back to Care strategy (n=4), which traces patients defaulting on treatment and the patient appointment system (n=4) designed to reduce waiting times. KMC (n=3) was the most frequent process innovation for district hospitals.

Business model innovations

Models such as the Central Chronic Medicine Dispensing and Distribution (CCMDD, n=10), which allows stable patients to collect chronic medication from external pick-up points and Ward-Based Outreach Teams (WBOTs, n=9), delivering PHC services through Community Health Workers (CHWs), were the most diffused at primary care level. Optimised sample transportation and collection (n=4) was the most common model by NHLS, improving turnaround times through streamlined logistics. Central

Table 5 Innovation category by geographic location*

Settlement type	Product n (%)	Process n (%)	Business model n (%)	Total frugal innovations per settlement type
Urban	31 (35.6%)	29 (33.3%)	27 (31.0%)	87
Rural	10 (35.7%)	5 (17.9%)	13 (46.4%)	28
P value	0.004	0.178	0.031	

*Percentages are row percentages (within settlement type).

Table 6 Distribution of the most diffused innovations

Facility type	Product innovations (no.)	Process innovations (no.)	Business model innovations (no.)
NHLS laboratories	POCT (n=5), Webview (n=3)	Laboratory automation (n=8), e-Lab (n=4), eGK (n=5)	Optimised sample transportation and collection (n=4)
District hospitals	POCT (n=5), HPRS (n=2), MomConnect (n=1), Webview (n=1), Virtual platforms (n=3)	KMC (n=3), appointment system (n=1)	Partnerships with external stakeholders (n=2)
PHC clinics	HPRS (n=8), MomConnect (n=5) Webview (n=1), Virtual platforms (n=1)	Tracking and back to care (n=4) AYFS (n=4), appointment system (n=3), e-Lab (n=1)	CCMDD (n=10), WBOTs (n=9) Partnerships with NGOs/private providers (n=6)
Central hospitals	Virtual platforms (n=1)	Varied	Central hospital outreach (n=2)

AYFS, Adolescent and Youth Friendly Services; CCMDD, Central Chronic Medicines Dispensing and Distribution; eGK, electronic gatekeeping; HPRS, Health Patient Registration System; KMC, Kangaroo Mother Care; NGOs, Non-governmental Organisations; NHLS, National Health Laboratory Service; PHC, primary healthcare; POCT, Point of Care Testing; WBOTs, Ward-Based Outreach Teams.

hospitals were dominated by central hospital outreach services (n=2), extending specialist services to district hospitals to improve access and reduce patient travelling costs.

Innovation origin (push vs pull)

Push innovations were defined as top–down solutions originating externally but implemented within facilities, while pull innovations referred to bottom–up solutions internally developed by facilities. Most innovations observed were of push origin, initiated by the government (online supplemental file 13). χ^2 revealed a statistically significant association between innovation origin and both product and business model innovations (p=0.001 each). There was no significance found for process innovations (p=0.121). There was also no significant association between innovation origin and facility type (online supplemental file 14).

DISCUSSION

This study mapped innovations across the public health system, unearthing adaptive solutions that emerged despite challenges. Using a frugal lens, and classifying innovations into product, process and business models, revealed an ecosystem of strategies addressing accessibility, affordability and adaptability requirements.

Although Arshad *et al*[18] reported a predominance of product innovations (76%) compared with process innovations (18%) among 50 healthcare FIs, our study revealed a balanced distribution across all innovation categories. Of the 115 innovations that met the frugality criteria, product innovations represented 36% (n=41), closely followed by business model innovations at 35% (n=40), while process innovations accounted for 30% (n=34). These differences likely reflect contrasting study contexts. Arshad *et al*[18] largely focused on innovations originating from multinational corporations, grassroots entrepreneurs, non-governmental organisations (NGOs) and small and medium enterprises (SMEs), while our study explored innovations emerging within the public health sector where adaptive care delivery models and institutional arrangements play a critical role to improve access under resource constraints. FI, given its multidimensional nature, intersects technological, social and institutional domains.[14] It encompasses diverse factors, from antecedents like the need to address healthcare challenges, mediators like institutional constraints, to consequences such as improved service access.[38] Some are push/top–down, while others are pull/bottom–up driven. Although often under-reported in literature,[23] the limited scholarly attention of FI in South Africa, despite systemic constraints, is surprising given that this study has found several. Advanced economies too are exploring strategies to leverage FIs.[26 28] Among the few documented examples in South Africa are grassroots social FIs,[39] medical devices from manufacturing firms[40] and social entrepreneurial initiatives.[41]

Beyond the overt categorisation of innovations as product, process or business model, we next discuss selected cases from our study in light of how technology, social and institutional concerns explain the close relationship between the context and the type of intervention.

Product innovations

NHLS reported the highest number of frugal product innovations, including POCT blood gas analysers deployed to hospital wards under service-level agreements. While the analysers constitute health product innovations, their mode of deployment reflects an important form of institutional innovation. Using this model, the NHLS retains ownership of the technology and provides operational oversight, quality assurance and maintenance, allowing hospitals to use the POCT devices without incurring capital costs or administrative responsibilities.

POCT diffusion demonstrates how technological innovations enhance access and turnaround times, consistent with literature showing that POCT can be the only viable diagnostic solution in resource-limited settings with poor access to laboratories.[42]

At PHC level, the HPRS, a national e-Health initiative,[16] was among the most frequently reported product innovations. Its presence addresses documented challenges in the country's healthcare system related to fragmented record-keeping, patient traceability and associated institutional risks such as litigation arising

from lost or incomplete records. It has been reported to also mitigate opportunities for practices such as 'medication shopping', a social problem created by weak institutions, where patients collect medication from multiple facilities. MomConnect, a government-led initiative with private sector support, was also identified at PHC level, reflecting its social role in expanding access to free antenatal education, including in rural and underserved communities.[43]

Process innovations

Laboratory automation was among the most frequently identified process innovations in central and tertiary laboratories. Its presence is consistent with its documented evidence of enhancing workflow efficiency, reducing testing errors, delivering rapid results and releasing laboratory staff to focus on more value-adding activities.[44]

At district hospitals, KMC emerged as the most frequently reported process innovation. The adoption of this innovation in district hospitals highlights its beneficial impact, consistent with existing literature which identifies KMC as a cost-effective intervention that reduces the reliance on expensive technical solutions such as incubators and thereby contributes to reductions in infant mortality in resource-limited settings.[27 45]

At PHC level, Tracing and Back to Care strategy, where CHWs locate and reintegrate patients into the health system, emerged as a recurring process innovation. These approaches are well-documented responses to challenges of treatment interruption among chronic patients to reduce default rates,[46] illustrating how institutional and social innovations respond to contextual challenges.

Business model innovations

At PHC level, CCMDD was the most frequently reported business model innovation. Its widespread adoption is consistent with national strategies to decongest facilities by decentralising chronic medication delivery and allowing stable patients to collect medicines from private providers,[16] including through alternative arrangements such as 'fast queues' in rural areas lacking private pharmacies.

The WBOTs and partnerships with NGOs or private providers were also common business models at PHC-level, demonstrating adaptive responses to extend primary care beyond facilities through community-based approaches and cross-sector collaborations, consistent with studies on strengthening institutions for greater access and continuity of care in underserved settings.[47 48]

Within NHLS, optimised sample transportation was reported across several sites, reflecting documented institutional reorganisations to optimise specimen collections from clinical facilities to laboratories in a timely, cost-effective manner despite limited resources as observed elsewhere.[49]

Although central hospitals are recognised for innovation, data were limited due to the small sample size.[3] Notable initiatives included outreach programmes that decentralise specialised surgery by leveraging underused district-hospital theatres. These public–private partnerships reduce travel costs and waiting times, demonstrating the value of mobilising external networks to achieve healthcare objectives.[48]

Dynamics on innovation origin and geography

A dominance of push innovations was observed, driven by government or pathology leadership. Of the 201 innovation instances, 178 (89%) were push innovations, originating from top–bottom initiatives, rather than bottom–up as suggested by prior literature.[18 39] However, our findings align with literature suggesting that innovations directed through policy mandates improve adoption but may fail without dedicated funding.[7 50]

Pull innovations were less common (23 cases or 11.4%), supporting calls for bottom–up approaches driven by frontline staff to respond to local contexts.[50] Such innovations can improve efficiency, productivity and sustainability.[50] A hybrid approach balancing national priorities with context-sensitive, staff-initiated solutions could achieve more equitable outcomes. Urban settings more frequently reported product innovations, while rural facilities reported a relatively higher proportion of business model innovations, highlighting the role of context-driven responses to local constraints.

Impact on the healthcare system

Analysing these innovations through a frugal lens reveals how LMICs constraints become catalysts for innovation. Classification into product, process and business models, and assessed along accessibility, affordability and adaptability, align with UHC objectives for equity. While scholars have documented diverse FIs that support the UHC goals, this study has extended that effort to the South African context.[18 21]

The widespread presence of FIs in South Africa underscores their relevance in addressing contextual challenges and potential to transform healthcare delivery. Yet, they need to be further understood in terms of types of innovations they are and how they link to the context. For instance, technological innovation highlights how resource constraints can be overcome to develop context-appropriate solutions; social innovation addresses affordability constraints, while institutional innovation demonstrates how equitable access can be achieved despite institutional voids.[25]

Future research could undertake detailed in-depth case studies to trace the developmental trajectories of these innovations in order to better understand the contextual factors that enable their emergence,

adaptation and sustainability. Policymakers may also benefit from institutionalising a culture of FI within the health sector, thereby advancing progress towards achieving UHC goals. As part of our broader multiphase project, the next phase will involve analysing these innovations in greater depth to assess their alignment with South Africa's NHI principles. The current mapping presented in this paper provides a foundational evidence base, offering a systematic mapping, classification and prevalence data on which these subsequent evaluative efforts can build on.

Study limitations

There are some limitations in this study. First, although individual innovation instances were identified and documented, this analysis focused on aggregated prevalence patterns and innovation characteristics by category and facility type rather than specific innovation cases. Future research can build on these findings to generate deeper insights. Second, given the purposive sampling approach, the results do not provide a statistically representative national prevalence but a snapshot of the types, distribution and frugal characteristics of innovations identified at sampled public sector facilities. The approach prioritised relevance of innovations over representativeness, which is appropriate for the exploratory nature of the study. Nevertheless, we consider the findings transferable to comparable public health settings with similar resource-constraints. Statistical associations should be cautiously interpreted due to non-random sampling. Third, the assessment of FIs relied on contextual judgements of participants captured through SAQs, which are inherently subjective. This was mitigated by having independent ratings from two participants per innovation and using average scores to improve reliability.

CONCLUSIONS

The study mapped public sector healthcare innovations across South Africa and assessed their frugal characteristics on accessibility, affordability and adaptability dimensions. The findings reveal an ecosystem of FIs at different facilities and geographical regions, responding to local constraints, as reflected by the reported types of innovation. The observed distribution of product, process and business model innovations, as well as based on their origins as push (top–down) or pull (bottom–up), illustrate how the public health sector employed adaptive technological, social and institutional arrangements to respond to systemic pressures. The findings provide empirical evidence for further researching how FIs can contribute to the health system and inform ongoing efforts to advance UHC objectives under the NHI.

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