

Population Health Management in Saudi Arabia: AI Integration Review

A Systematic Review of Policy, Practice, and Outcomes

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ABSTRACT

Saudi Arabia's Vision 2030 has initiated a comprehensive restructuring of the national healthcare system, positioning Population Health Management (PHM) as a central pillar for achieving sustainable, value-based healthcare delivery. This study presents a systematic narrative review of the evolution, policy framework, implementation strategies, and early performance outcomes of PHM within the Saudi healthcare system. Guided by PRISMA-based methodological rigor, the review synthesizes foundational population health theory, international implementation science literature, national reform policies, and empirical evidence from cluster-level implementation.

Findings indicate that Saudi Arabia has developed a structured PHM framework anchored in established population health theory and operationalized through the Council of Health Insurance (CHI) five-step PHM cycle. The Qassim Health Cluster case demonstrates large-scale screening implementation, structured disease prioritization under the 5x5 model, and regional governance alignment. Comparative macro-health indicators reveal that Saudi Arabia achieves population health outcomes comparable to high-expenditure systems while maintaining lower per capita healthcare spending, indicating strong structural efficiency.

However, despite policy alignment and early operational success, several implementation gaps persist, including limited dedicated PHM financing mechanisms, emerging digital interoperability infrastructure, workforce readiness constraints, and insufficient longitudinal outcome reporting. Benchmarking against international PHM implementation domains suggests that Saudi Arabia is currently in a Structured Early Expansion Phase.

This review further examines the critical role of Artificial Intelligence (AI) in advancing the PHM agenda — including AI-enabled population segmentation, predictive risk stratification, clinical decision support, and hospital management information systems (HMIS) — highlighting both proven applications and unresolved implementation challenges within the Saudi context.

Strengthening financing models, digital integration, AI infrastructure, workforce specialization, and performance monitoring systems will be critical to scaling PHM nationally. With sustained governance commitment and strategic alignment under Vision 2030, PHM has the potential to enhance cost-efficiency, equity, and long-term health system sustainability across the Kingdom.

Keywords: Population Health Management (PHM); Vision 2030; Saudi Healthcare Reform; Value-Based Healthcare; Health Clusters; Chronic Disease Management; Artificial Intelligence (AI); Hospital Management Information Systems (HMIS); Digital Health Integration; Predictive Analytics; Health System Transformation; Healthcare Sustainability.

1. INTRODUCTION

1.1 The Global Imperative for Population Health Management

Healthcare systems worldwide confront unprecedented challenges: aging populations, rising chronic disease burdens, escalating costs, and persistent health inequities. Traditional episodic, fee-for-service care models have proven inadequate for addressing these

complex, interconnected challenges (Thomas, 2022). Population Health Management (PHM) has emerged as a transformative paradigm that shifts healthcare delivery from reactive, illness-focused care to proactive, data-driven population health improvement (Kindig & Stoddart, 2003).

PHM encompasses the health outcomes of a population group, the distribution of these outcomes, and the policies, interventions, and care delivery

models that influence these outcomes (National Committee for Quality Assurance, 2018). Unlike traditional public health, PHM operates at the intersection of clinical care delivery, population health science, and health system management—requiring integration across previously siloed domains (Lantz, 2019).

Increasingly, Artificial Intelligence (AI) has emerged as a pivotal enabler within PHM. AI's capacity for automation, predictive modeling, and large-scale data analysis offers transformative potential for population segmentation, risk stratification, and proactive care coordination—capabilities at the very core of effective PHM (Karrar et al., 2025).

Nidhi Shashikumar et al. 2026, proposed a data-driven framework integrating predictive maintenance and inventory optimization in medical device supply chains. The study employs hybrid machine learning models such as Random Forest, LSTM, and XGBoost to predict equipment failures, while ARIMA is used for demand forecasting. The integration of these models enables proactive maintenance scheduling and optimized inventory control, reducing equipment downtime, minimizing overstocking and shortages, and improving overall supply chain efficiency. The findings highlight that combining predictive analytics with inventory management enhances operational reliability, reduces costs, and supports better decision-making in healthcare logistics [15].

1.2 Saudi Arabia's Health System Transformation Agenda

The Kingdom of Saudi Arabia (KSA) has embarked on one of the most ambitious health system transformations globally through Vision 2030, launched in 2016 (Alasiri & Mohammed, 2022). This national blueprint seeks to diversify the economy, reduce oil dependence, and fundamentally restructure public services—including healthcare. The Health Sector Transformation Program, one of Vision 2030's eight realization programs, aims to restructure the health sector into a comprehensive, integrated, value-based system that improves population health while ensuring financial sustainability (Mani & Goniewicz, 2024).

Saudi Arabia's transformation is particularly noteworthy given its unique characteristics: a single-payer universal healthcare system, rapid demographic transition, high chronic disease prevalence (obesity 33%, diabetes 17%, hypertension 19% in Qassim region), and healthcare spending of 9.2% GDP—approximately half that of the United States (Young et al., 2021; Alharbi et al., 2025). AI technologies, including predictive analytics and intelligent clinical decision support, are actively being integrated into this transformation agenda, with the Saudi government

committing a USD 40 billion technology fund to advance AI across sectors including healthcare (Karrar et al., 2025).

1.3 Rationale and Objectives

Despite growing policy attention and implementation activity, no comprehensive review has synthesized Saudi Arabia's PHM journey alongside the emerging role of AI. Critical questions remain unanswered: How did PHM evolve within Saudi Arabia's unique historical and institutional context? What constitutes the national PHM framework? What are the real-world implementation experiences, challenges, and lessons? How does AI integrate with and enhance PHM in the Saudi context? How does Saudi Arabia's PHM approach compare with international best practices? This systematic review addresses these gaps through four specific objectives:

1. To trace the historical evolution of population health approaches within Saudi Arabia's health system transformation (1925–2030)
2. To analyze the national PHM policy framework established by the Council of Health Insurance (CHI), including its theoretical underpinnings, operational guidance, and implementation requirements
3. To evaluate real-world PHM implementation through the Qassim Health Cluster case study, synthesizing challenges, strategies, outcomes, and lessons learned
4. To examine the role of Artificial Intelligence in advancing PHM and Hospital Management Information Systems (HMIS) in Saudi Arabia, and to develop an evidence-informed framework for scaling AI-enabled PHM across the Kingdom.

2. METHODS

2.1 Study Design

This study employed a systematic review design aligned with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, adapted for policy and implementation research. Given the heterogeneous nature of included documents (peer-reviewed research, policy guidance, implementation reports), we utilized a narrative synthesis approach with thematic analysis.

2.2 Search Strategy and Document Selection

We conducted comprehensive searches of PubMed, Google Scholar, and the Saudi Ministry of Health and Council of Health Insurance publication repositories. Search terms included combinations of: "Saudi Arabia," "Vision 2030," "population health management," "health system transformation,"

"Qassim Health Cluster," "value-based healthcare," "artificial intelligence in healthcare," "HMIS," and "universal health coverage."

Inclusion criteria were: (1) English language; (2) published 2016–2025; (3) focused on Saudi Arabian health system, PHM, AI in healthcare, or health transformation; (4) peer-reviewed articles, official policy documents, government reports, or

implementation evaluations. Exclusion criteria were: (1) opinion pieces without empirical or policy content; (2) documents focused exclusively on clinical interventions without PHM or AI context; (3) duplicate publications.

Four documents formed the core analytical corpus (Table 1):

Table 1: Summary of Core Analytical Documents

Document	Type	Focus	Population / Scope	Key Contributions
Alharbi et al. (2025)	Peer-reviewed implementation study	Qassim Health Cluster PHM	1.33M population; 102,946 screened; 11 key informants	Real-world implementation challenges, strategies, lessons; diabetes outcomes
Young et al. (2021)	Peer-reviewed comparative analysis	KSA–US health system comparison	National-level KSA vs USA 1960–2019	Historical evolution (5 phases); WHO building blocks analysis; outcomes comparison
CHI (2024)	National policy guidebook	PHM framework for private sector	All privately insured beneficiaries	5-step PHM cycle; roles/responsibilities; prioritization; measurement framework
Karrar et al. (2025)	Peer-reviewed review article	AI in Hospital Management Information Systems	KSA and global healthcare settings	AI applications (predictive analytics, NLP, RPA, CDSS); benefits; challenges; KSA AI initiatives

2.3 Data Extraction and Analysis

We developed a standardized data extraction framework based on four theoretical lenses: (1) WHO Health System Building Blocks; (2) PHM Cycle Framework; (3) Implementation Science domains; and (4) AI Integration Framework covering technology readiness, data infrastructure, workforce capacity, and ethical governance. Two reviewers independently extracted data; discrepancies were resolved through consensus. Thematic analysis was conducted using NVivo software.

2.4 Quality Assessment

For peer-reviewed articles, quality was assessed using the Mixed Methods Appraisal Tool (MMAT). The CHI Guidebook was assessed for comprehensiveness, clarity, evidence base, and stakeholder consultation using adapted criteria for policy document analysis. The AI review (Karrar et al., 2025) was assessed for breadth of evidence synthesis, recency of sources, and contextual applicability to the Saudi setting.

3. RESULTS

3.1 Historical Evolution of Population Health Approaches in Saudi Arabia

Our analysis reveals five distinct phases in Saudi Arabia's health system evolution, each contributing foundational elements to contemporary PHM implementation (Young et al., 2021).

Phase 1 — Local Leadership (1925–1950): The foundational phase established rudimentary public health infrastructure focused on pilgrimage-related health and infectious disease control. Despite limited resources, this period created the institutional precursors for modern health governance.

Phase 2 — Centralized Planning (1951–1970): MOH establishment centralized health authority, enabling systematic planning. School health units represented early targeted population health interventions, albeit limited to urban males.



Phase 3 — Growth (1971–1990): Oil revenue enabled unprecedented infrastructure expansion. Critically, this period demonstrated that health system investment directly improved population outcomes— infant mortality declined from 250 to 19.1 per 1,000 live births. However, oil price volatility revealed sustainability vulnerabilities.

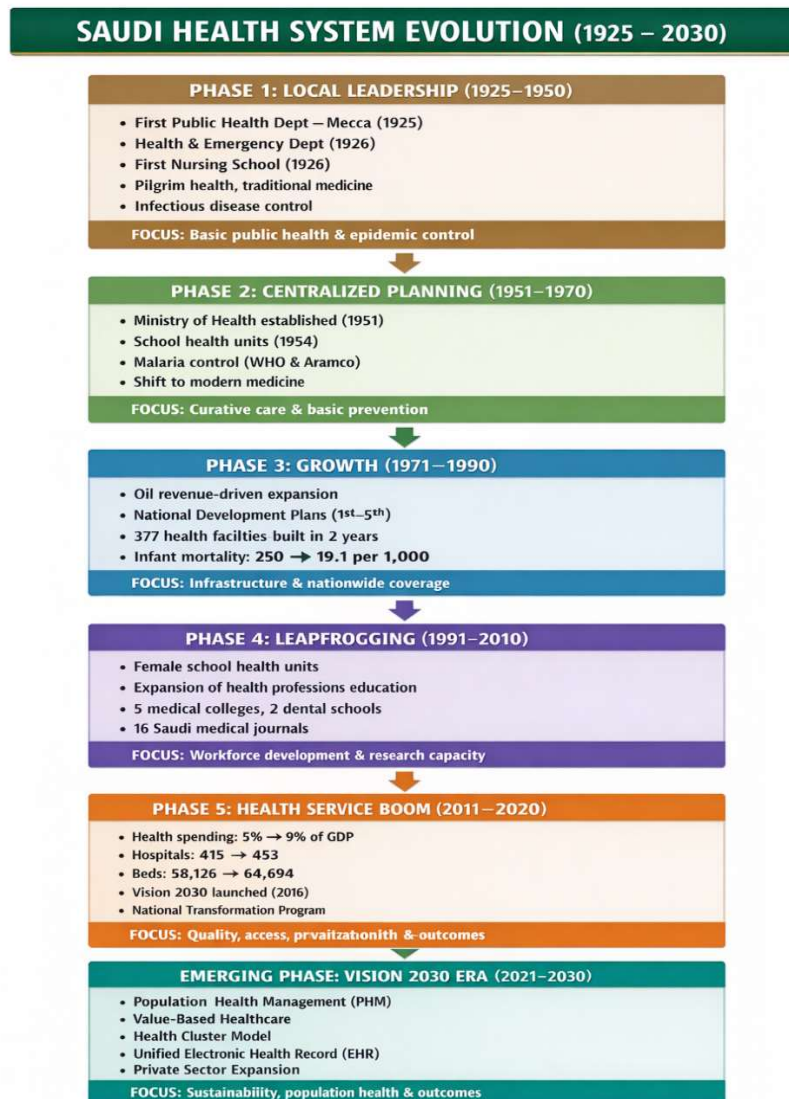
Phase 4 — Leapfrogging (1991–2010): Workforce development and health research capacity expanded dramatically. The inclusion of female school health units addressed previous gender inequities. Medical education expansion created indigenous workforce capacity, reducing international dependency.

Phase 5 — Health Service Boom (2011–2020): Healthcare spending nearly doubled, enabling facility

expansion. Vision 2030's launch catalyzed the paradigm shift from volume to value. The National Transformation Program established measurable healthcare targets aligned with international benchmarks.

Emerging Phase — Vision 2030 Era (2021–2030): Current phase characterized by PHM national framework adoption, health cluster implementation, e-health expansion, private sector integration, and — critically — the accelerated deployment of AI-enabled health technologies. Saudi Arabia's AI health initiatives, including Mini GPT-Med, Eyenai for diabetic retinopathy, and AI-supported cancer screening at Seha Virtual Hospital, represent the digital maturation of this phase (Karrar et al., 2025).

Figure 1: Five Phases of Saudi Health System Evolution (1925–2030)





3.2 National PHM Policy Framework: The CHI Population Health Management Guidebook

3.2.1 Theoretical Foundations

The CHI PHM Guidebook (2024) represents Saudi Arabia's first comprehensive national PHM policy framework, specifically designed for the private insurance sector but with transferable principles for the entire health system. The Guidebook explicitly adopts Kindig and Stoddart's (2003) definition of population health. PHM is conceptualized as "a care model that addresses the population and individuals' health needs at all points along the continuum of care through the development of data-driven, cost-effective and evidence-based interventions" (CHI, 2024, p. 11). This framework integrates three intellectual traditions: (1) chronic care model (proactive, planned care); (2) value-based healthcare (outcomes relative to costs); and (3) implementation science (evidence-to-practice translation). AI-enabled analytics are increasingly recognized as a fourth enabling pillar, providing the data infrastructure necessary to operationalize each of these traditions at scale (Karrar et al., 2025).

3.2.2 The CHI PHM Cycle

The Guidebook operationalizes PHM through five sequential, iterative steps:

Step 1 — Define and Understand the Population:

CHI conducts population-wide segmentation using an adapted Bridges to Health framework, categorizing beneficiaries into nine core groups and 15 sub-segments. Risk stratification tools include the Charlson Comorbidity Index, AAFP Two-Step, Johns Hopkins ACG®, and 3M™ CRG, which help identify varying levels of health risk and care needs across the population. AI-driven predictive analytics can substantially enhance this step by processing large-scale, multi-dimensional datasets, including electronic health records (EHRs), claims data, and social determinants of health. These techniques enable the identification of hidden patterns, early risk signals, and high-cost patient groups that may not be captured through traditional actuarial approaches, thereby supporting more precise and proactive population segmentation (Karrar et al., 2025).

Step 2 — Design and Prioritize Interventions:

The Guidebook emphasizes evidence-based intervention selection aligned with the continuum of care, ranging from preventive to chronic and complex care management. A sample intervention menu is provided for CHI's five priority conditions—coronary heart disease, diabetes/pre-diabetes, hypertension, obesity, and tobacco use. AI-based clinical decision support systems (CDSS) can further strengthen this process by integrating patient-specific clinical data, real-time monitoring inputs, and updated clinical guidelines. These systems can generate personalized care pathways, prioritize interventions based on risk severity, and assist clinicians in selecting the most effective and cost-efficient strategies, thereby improving care outcomes and resource allocation.

Step 3 — Implement Interventions:

Implementation guidance addresses governance structures, policy alignment, workforce capacity building, and care integration across primary, secondary, and tertiary levels. It also highlights the importance of multidisciplinary collaboration and efficient workflow management. AI-powered robotic process automation (RPA) can streamline routine administrative and operational tasks such as patient registration, appointment scheduling, billing, and care coordination. This reduces manual workload, minimizes human errors, and enhances process efficiency. Additionally, AI tools can support remote monitoring and telehealth integration, enabling continuous patient care and improving accessibility, especially in underserved areas (Karrar et al., 2025).

Step 4 — Measure and Evaluate Interventions:

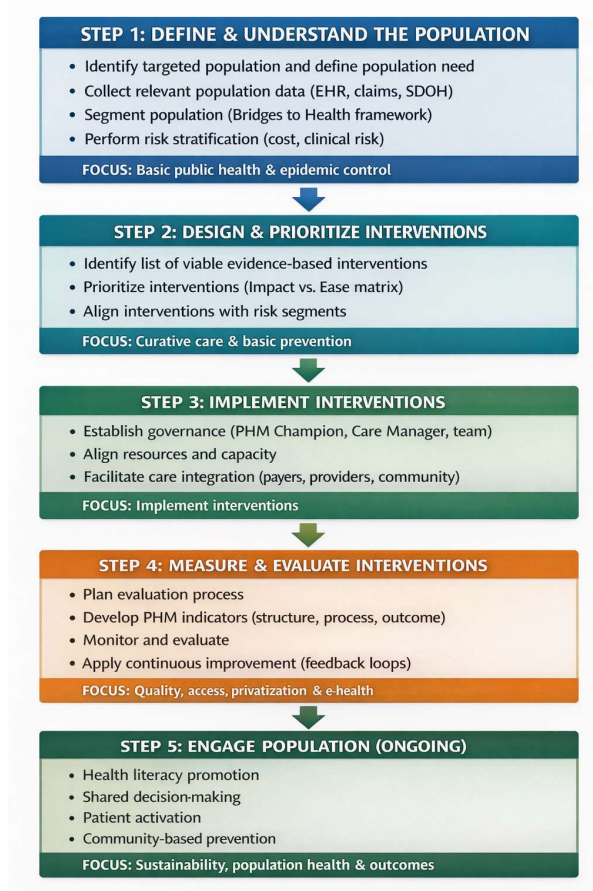
The measurement framework adopts Donabedian's structure–process–outcome paradigm to ensure comprehensive

evaluation of healthcare delivery. CHI provides standardized core measures adapted from HEDIS, AHRQ, and OECD indicators, covering quality, efficiency, and patient outcomes. AI-enabled analytics platforms, dashboards, and natural language processing (NLP) tools can automate data extraction from clinical records, identify inconsistencies, and flag documentation gaps. These technologies enable real-time monitoring, predictive performance analysis, and dynamic reporting, thereby improving transparency, accountability, and evidence-based decision-making while significantly reducing the administrative burden associated with population health management (PHM).

Step 5 — Engage Population (Ongoing): Population engagement is conceptualized as

a continuous and cross-cutting component across all PHM phases, emphasizing patient-centered care and active participation. AI-driven chatbots, virtual health assistants, and personalized digital health platforms can enhance engagement at scale by delivering tailored health education, medication reminders, lifestyle recommendations, and appointment management services. These tools can adapt communication strategies based on individual risk profiles, preferences, and behavioral patterns, thereby improving adherence, patient satisfaction, and long-term health outcomes. Furthermore, AI can facilitate two-way communication, enabling timely feedback and strengthening the relationship between healthcare providers and the population (Karrar et al., 2025).

Figure 2: CHI Population Health Management Cycle



3.2.3 Stakeholder Roles and Responsibilities

The Guidebook delineates explicit responsibilities across CHI, payers, and providers (Table 2). Emerging AI platforms will redistribute some of these responsibilities — for example, CHI could deploy

centralized AI population segmentation tools accessible to payers and providers, reducing duplication and improving data quality.

Table 2: CHI PHM Framework — Stakeholder Roles and Responsibilities

PHM Cycle Stage	CHI Role	Payer Role	Provider Role
Define & Understand Population	Sets KSA priority conditions; population segmentation	Identifies local needs; claims data integration	Applies risk stratification; clinical data collection
Design & Prioritize Interventions	Provides intervention menu and prioritization methodology	Supports providers in intervention selection	Identifies viable interventions; applies prioritization
Implement Interventions	Provides guidance; coordinates piloting	Aligns resources; establishes governance	Deploys workforce; delivers interventions
Measure & Evaluate	Sets indicators; benchmarks; baselines	Supports indicator selection and evaluation	Monitors; evaluates; continuous improvement
Population Engagement	Population-level engagement strategies	Supports beneficiary engagement	Delivers patient-level engagement interventions

3.2.4 Priority Conditions: The 5x5 Program

CHI's Population Health 5x5 Program (2021–2025) targets five high-prevalence, high-cost conditions: coronary heart disease, diabetes/pre-diabetes, hypertension, obesity, and tobacco use. These conditions were selected based on burden of disease, cost impact, and amenability to preventive interventions. AI tools — particularly machine learning models trained on local epidemiological data — have demonstrated significant utility in predicting individuals at risk of progressing in each of these categories, enabling earlier and more targeted intervention.

commenced), implementation, and evaluation. Diabetes mellitus was selected as the initial priority condition for Phase 1, with interventions focused on case finding, HbA1c monitoring, and glycemic control.

Implementation strategies included: (1) establishing direct communication channels with extra-regional departments; (2) developing local PHM policies and procedures; (3) utilizing data and evidence to secure administrative support; (4) creating shared vision through stakeholder engagement; (5) raising awareness and education across departments.

3.3 Implementation in Practice: The Qassim Health Cluster Experience

3.3.1 Context and Population

Qassim region, centrally located with 1.336 million population (2023 census), operates 20 hospitals (>2,900 beds), 156 PHC centers, and employs approximately 26,000 healthcare workers. The region exhibits higher-than-national chronic disease prevalence: obesity 33% (national 28.7%), diabetes 17% (national 13.4%), hypertension 19% (national 25%) (Alharbi et al., 2025). These disparities positioned Qassim as an ideal PHM implementation site and demonstrate the particular value of AI-driven early identification of at-risk populations.

3.3.2 Implementation Approach

The QHC PHM implementation team developed a 5-year strategic plan (2021–2026) aligned with the national PHM framework. The plan encompasses three management cycle stages: planning (Q2 2021

3.3.3 Implementation Outcomes

Quantitative Outcomes: Between Q1–Q3 2024, QHC screened 102,946 individuals. Among screened populations, prevalence was: hypertension 4.78%, diabetes 5.81%, obesity 11.63%. HbA1c uptake was significantly higher among Saudi nationals (5.45%) versus non-Saudis (4.52%; $p < 0.001$), but glycemic control showed no significant difference by nationality ($p = 0.395$), suggesting equitable outcomes once accessed.

Qualitative Findings: Thematic analysis of 11 key informant interviews revealed three major thematic areas: Implementation Challenges (policy guidance gaps, technical support deficiencies, resource constraints, stakeholder resistance, collaboration barriers); Implementation Strategies (policy development, communication enhancement, leadership engagement, capacity building); and Lessons Learned (training impact, problem-solving, leadership development, communication centrality).



3.3.4 Comparative Health System Performance

Young et al. (2021) provide critical context demonstrating that Saudi Arabia's health system

transformation has produced remarkable population health outcomes despite substantially lower spending (Table 3).

Table 3: Saudi Arabia–USA Health System and Outcome Comparison (2019)

Indicator	Saudi Arabia	USA
Life expectancy at birth (years)	74.9	78.5
Life expectancy gain 1960–2019	+29.2 years	+8.7 years
Infant mortality (per 1,000 live births)	2.0	2.0
Maternal mortality (per 100,000)	17	23
Health expenditure (% GDP)	9.2%	18.0%
Hospital beds (per 10,000)	27.0	29.0
Physicians (per 10,000)	24.0	26.0
Nurses/midwives (per 10,000)	57.0	85.5
Measles vaccination	98%	92%
Obesity prevalence	52.9%	39.8%
Diabetes prevalence	7.8%	9.4%
Hypertension prevalence	48.4%	32.1%

Source: Young et al. (2021), adapted from WHO, World Bank, UNICEF, Saudi MOH data

3.4 The Role of Artificial Intelligence in Advancing PHM and Healthcare Delivery in Saudi Arabia

A critical and emerging dimension of Saudi Arabia's PHM implementation agenda is the integration of Artificial Intelligence (AI). Based on a systematic review by Karrar et al. (2025) published in the Saudi Journal of Clinical Pharmacy, AI is rapidly becoming a fundamental component of Hospital Management Information Systems (HMIS) — the operational infrastructure upon which PHM programs depend. This section synthesizes key AI applications, demonstrated benefits, implementation challenges, and Saudi Arabia's specific AI healthcare trajectory.

3.4.1 AI Applications Directly Enabling PHM

Five AI application domains have particular relevance to PHM implementation:

Predictive Analytics for Population Risk Stratification: AI algorithms analyze patient admission patterns, seasonal variations, demographic data, and longitudinal health records to forecast patient volumes and identify high-risk individuals. In PHM terms, this directly supports Step 1 (population definition) and Step 2 (intervention prioritization) of the CHI PHM Cycle. Mount Sinai Health System's AI predictive platform demonstrated significant reductions in patient waiting times by accurately anticipating seasonal demand — a directly applicable use case for Saudi health clusters managing chronic disease populations (Karrar et al., 2025).

Clinical Decision Support Systems (CDSS): AI-augmented CDSS deliver real-time, evidence-based guidance to healthcare practitioners by analyzing patient data, medical histories, and contemporary

clinical guidelines. For PHM's priority conditions (diabetes, hypertension, coronary heart disease, obesity, tobacco use), AI-CDSS can recommend evidence-based treatment pathways, flag medication interactions, and alert clinicians to deteriorating risk profiles. Cleveland Clinic's AI-CDSS demonstrated measurable reductions in medical errors and improved diagnostic precision (Karrar et al., 2025).

Natural Language Processing (NLP) for Documentation and Monitoring: NLP enables automated analysis of unstructured clinical notes and discharge summaries, detecting documentation gaps and ensuring completeness. For PHM's measurement and evaluation step, NLP can automate extraction of quality indicators from clinical records — a significant advancement over manual data abstraction. Mayo Clinic's NLP implementation improved documentation accuracy and regulatory compliance while reducing clinician documentation time (Karrar et al., 2025).

Robotic Process Automation (RPA) for Administrative Efficiency: RPA automates repetitive administrative tasks including billing, claims processing, appointment scheduling, and care coordination workflows. By relieving healthcare personnel of administrative burdens, RPA enables greater focus on patient-facing PHM activities. Intermountain Healthcare's RPA implementation decreased billing cycle duration and reduced claims denial rates, improving operational efficiency applicable to Saudi insurance-provider PHM models (Karrar et al., 2025).

Patient Engagement Tools: AI-driven chatbots, virtual health assistants, and personalized patient portals



address PHM's ongoing population engagement requirement at scale. Northwell Health's AI chatbot reduced administrative staff workload while improving patient engagement scores and medication compliance — outcomes directly aligned with PHM's cross-cutting engagement objective (Karrar et al., 2025).

3.4.2 AI in Hospital Management Information Systems (HMIS): Relevance to PHM

Infrastructure

HMIS constitute the operational backbone of PHM programs, integrating clinical, administrative, and financial data streams. Karrar et al. (2025) identify seven domains where AI enhances HMIS performance — each with direct PHM implications:

Table 4: AI-HMIS Enhancement Domains and PHM Implications

AI-HMIS Domain	Core Capability	PHM Implication
Improved Patient Care	Integrated data management; care team coordination	Supports Step 1 population understanding; enables coordinated chronic disease management
Operational Efficiency	Automated registration, scheduling, billing	Reduces administrative burden; frees resources for PHM activities
Data-Driven Decision Making	Advanced analytics; KPI monitoring; pattern identification	Enables PHM Step 4 measurement; supports performance reporting to CHI
Financial Management	Billing automation; revenue cycle optimization	Supports PHM business case; enables ROI tracking for interventions
Regulatory Compliance	Automated data entry; audit trail management	Ensures PHM data quality standards and CHI reporting requirements
Patient Engagement	Patient portals; bidirectional communication	Directly supports PHM Step 5 population engagement
Scalability & Adaptability	Flexible architecture for expanding services	Enables PHM program scaling across 20 Saudi health clusters

3.4.3 AI in Saudi Arabia's Healthcare Ecosystem

Saudi Arabia is not merely a passive recipient of global AI healthcare developments — it is actively establishing itself as a regional leader in health AI innovation. Karrar et al. (2025) document a portfolio of significant national AI health initiatives:

- **Mini GPT-Med:** Developed by King Abdullah University of Science and Technology (KAUST) in collaboration with Saudi Data and Artificial Intelligence Authority (SDAIA). A vision-integrated AI language model proficient in diagnosing 14 distinct diseases, directly applicable to PHM's screening and early detection objectives.
- **Eyenai:** Developed in partnership between SDAIA and King Khaled Eye Specialist Hospital. An AI solution for diabetic retinopathy detection — a high-priority complication of diabetes, one of PHM's core 5x5 conditions.
- **AI-Powered Cancer Screening:** Seha Virtual Hospital partnered with South Korean health technology firm Lunit to provide AI-powered solutions for breast cancer and tuberculosis screening —

extending PHM screening capabilities to population-level digital platforms.

- **Genomics and CAR-T Cell Therapy:** King Faisal Specialist Hospital and Research Center utilized AI to produce CAR-T cells for oncological therapy and conducted 7,000 whole-genome sequencing analyses — positioning Saudi Arabia at the frontier of precision medicine.
- **Brain Tumor Segmentation:** King Abdulaziz City for Science and Technology developed AI for enhanced brain tumor MRI segmentation, improving diagnostic precision.
- **USD 40 Billion Technology Fund:** The Saudi government's planned investment in AI with healthtech as a primary focus demonstrates national commitment to AI-enabled healthcare transformation at a scale unmatched in the region.

3.4.4 Benefits of AI Integration for PHM

Synthesizing the evidence from Karrar et al. (2025) and the PHM implementation literature, AI integration delivers six categories of benefit with direct PHM relevance: (1) Improved operational efficiency



through automation of repetitive administrative tasks; (2) Enhanced patient care quality through evidence-based CDSS recommendations; (3) Data-driven decision-making enabling population-level pattern recognition and targeted interventions; (4) Increased patient engagement through personalized digital health tools; (5) Cost reduction through process optimization, reduced errors, and better resource allocation; (6) Regulatory compliance and risk management through automated audit trails and drug interaction surveillance.

3.4.5 Challenges in AI Implementation for PHM

Notwithstanding these benefits, AI implementation in Saudi Arabia's PHM context faces significant challenges that directly mirror broader PHM implementation challenges identified in the Qassim Health Cluster experience (Karrar et al., 2025; Alharbi et al., 2025):

Data Privacy and Security: Healthcare organizations manage sensitive patient data governed by national regulations. AI requires access to extensive datasets, creating risks of data breaches and unauthorized access. Saudi Arabia is developing GDPR-equivalent data protection frameworks, but implementation across health clusters requires careful governance design.

Integration with Legacy Systems: Many Saudi health facilities operate legacy systems that may lack interoperability with contemporary AI applications. Infrastructure upgrades are costly and complex. The Qassim Health Cluster's experience of technical support deficiencies directly relates to this challenge.

Workforce Resistance and Training: Effective AI integration requires healthcare personnel endorsement. Concerns about job displacement and

insufficient AI literacy may generate resistance — mirroring the broader change management challenges documented in the QHC implementation. Organizations must invest in comprehensive AI training programs aligned with clinical workflows.

Algorithmic Bias and Ethical Implications: AI systems trained on biased or unrepresentative data may generate inequitable recommendations. In the Saudi context, ensuring AI models reflect the diverse patient population (Saudi nationals and expatriates) is critical for maintaining PHM's equity orientation. SDAIA is responsible for establishing ethical AI standards, but operationalizing these in clinical settings requires ongoing vigilance.

Implementation Costs: Acquiring AI technologies, upgrading infrastructure, and training staff represents significant upfront investment — particularly challenging for smaller facilities and health clusters with constrained PHM budgets. Return-on-investment frameworks must be developed to justify AI expenditures within PHM business cases.

Cultural and Islamic Ethical Considerations: Saudi Arabia's AI deployment must align with Islamic principles, particularly regarding individual privacy, gender equity, and transparency. SDAIA's mandate to advance AI while upholding ethical standards provides a governance framework, but clinical operationalization requires cultural sensitivity (Karrar et al., 2025).

3.5 Thematic Synthesis: Implementation Challenges and Facilitators

Cross-document thematic synthesis identified eight major themes spanning policy, implementation, and outcomes (Table 5).

Table 5: Thematic Synthesis of Saudi PHM Implementation

Theme	Description	Evidence Sources
1. Policy-Practice Gap	Disconnect between national policy intent and local implementation guidance	QHC: "No policy available"; "Guideline explains meaning but not implementation"
2. Centralized-Local Tension	Balance between national standardization and regional flexibility	CHI Guidebook: Centralized segmentation; QHC: Local policy development
3. Resource-Constrained Innovation	Achievement despite budget/technical support limitations	QHC: "How to work without a budget but achieve results"
4. Change Management Imperative	Stakeholder resistance as primary barrier	QHC: "Resistance to change"; "No understanding of PHM requirements"
5. Communication as Strategy	Communication, lobbying, negotiation as core PHM competencies	QHC: "Good communication and negotiations" (repeated)
6. Data-Driven Decision Making	Evidence utilization for leadership engagement and intervention targeting	CHI: Data-driven PHM cycle; QHC: "Utilizing data and evidence"



7. Leadership Development	Emergence of transformational leadership through implementation	QHC: "How can we become transformational leadership?"
8. AI as Enabler and Challenge	AI technologies enhance PHM capability but require governance, infrastructure and training	Karrar et al. (2025); KSA SDAIA initiatives; QHC digital gaps

4. DISCUSSION

4.1 Principal Findings

This systematic review provides the first comprehensive synthesis of Population Health Management evolution, policy, implementation, and AI integration in Saudi Arabia. Five principal findings emerge:

First, Saudi Arabia's PHM journey represents the culmination of a century-long health system evolution. Each historical phase contributed foundational elements: governance infrastructure (Phases 1–2), financing capacity and population health gains (Phase 3), workforce and research capacity (Phase 4), and value-orientation and digital infrastructure (Phase 5). Contemporary PHM implementation builds upon these accumulated capabilities.

Second, the CHI PHM Guidebook establishes a theoretically sound, operationally detailed national framework that compares favorably with international PHM models. Its explicit role delineation, structured PHM cycle, evidence-based intervention menu, and measurement framework provide clear implementation direction.

Third, the Qassim Health Cluster implementation demonstrates that systematic PHM is achievable within Saudi Arabia's existing health system infrastructure — with 102,946 individuals screened, policy development, and early outcome measurement. However, significant challenges reveal critical vulnerabilities requiring systemic attention.

Fourth, comparative health system analysis positions Saudi Arabia's PHM transformation within a broader narrative of efficient, effective health system performance — achieving near-US life expectancy and superior maternal mortality outcomes at approximately half the US health expenditure.

Fifth, Artificial Intelligence represents both the most promising enabler and one of the most complex challenges facing Saudi PHM scaling. AI capabilities in predictive analytics, CDSS, NLP, and patient engagement map directly onto PHM's five-step cycle — yet data governance, interoperability, workforce training, and ethical AI deployment present substantial implementation barriers requiring coordinated national strategy.

4.2 Positioning Saudi Arabia within International PHM Benchmarks

Saudi Arabia's PHM model combines centralized authority with emerging regional implementation capability. The CHI Guidebook's reach across the private insurance sector exemplifies this advantage. Compared to other Gulf Cooperation Council countries pursuing health transformation (UAE, Qatar), Saudi Arabia's approach is distinguished by its scale (34 million population), explicit PHM framework codification, and integration with broader economic transformation (Vision 2030).

The QHC experience aligns with international evidence that successful PHM implementation requires: (1) multi-level governance alignment; (2) dedicated implementation resources; (3) clinical engagement; (4) data infrastructure; (5) continuous learning systems (Steenkamer et al., 2020). AI integration adds a sixth dimension: intelligent data processing infrastructure that transforms raw population data into actionable clinical insights at a scale impossible through manual methods alone.

4.3 The PHM Maturity Model: A Framework for AI-Enabled PHM in Saudi Arabia

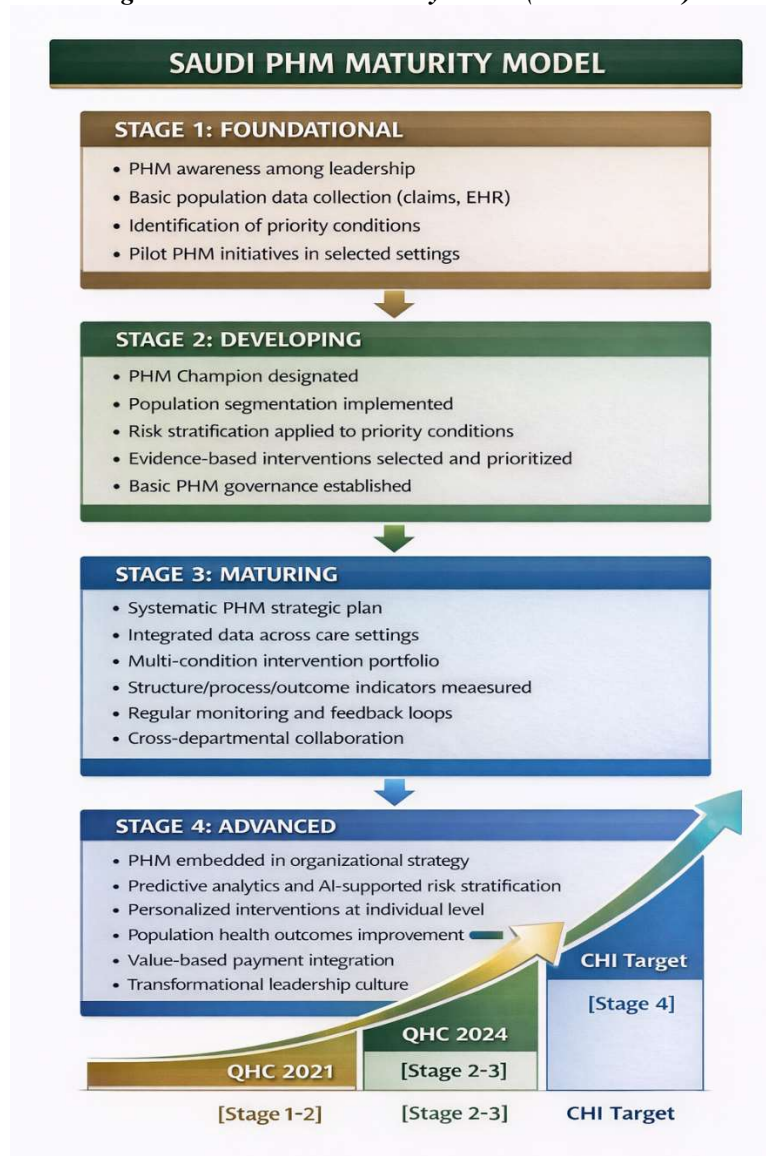
Synthesizing our findings, we propose an enhanced PHM Maturity Model for Saudi Arabia (Figure 3), conceptualizing PHM implementation as progressing through four developmental stages — now with AI integration as an explicit maturity dimension.

Stage 1 — Awareness: PHM awareness, pilot initiatives, early segmentation; minimal AI infrastructure. Stage 2 — Development: Systematic strategic planning, multi-condition focus, cross-departmental collaboration, early outcome measurement; AI pilots emerging. Stage 3 — Integration: Fully deployed PHM programs, advanced analytics integration, AI-CDSS operational, NLP-enabled documentation; AI embedded in workflows. Stage 4 — Transformation: Advanced AI population risk stratification, precision medicine approaches, value-based payment integration, demonstrable population health improvement; AI-driven continuous learning.

The Qassim Health Cluster in 2021 exhibited Stage 1–2 characteristics. By 2024, QHC demonstrated Stage 2–3 capabilities. The CHI Guidebook articulates Stage 4 expectations — and Saudi Arabia's national AI investments (SDAIA, USD 40 billion technology

fund, Eynai, Mini GPT-Med) create the enabling conditions for national Stage 4 achievement by 2030.

Figure 3: Saudi PHM Maturity Model (AI-Enhanced)



4.4 Critical Analysis: Tensions in AI-Enabled PHM

Universal Coverage vs. Targeted Interventions: Saudi Arabia's universal coverage model provides comprehensive entitlement but may diffuse focus from high-need populations requiring intensive AI-enabled interventions. PHM's risk stratification and targeted care management must coexist with universal entitlements.

Centralized AI Governance vs. Local Clinical Autonomy: AI deployment requires centralized

governance (data standards, model validation, bias monitoring) while clinical use demands local adaptation and workflow integration. Saudi Arabia's SDAIA provides the national governance framework, but health clusters need operational flexibility in AI tool adoption.

Technical AI Capability vs. Ethical AI Deployment: Technically superior AI models may conflict with cultural norms around privacy, gender, and human judgment. Saudi Arabia's Islamic ethical framework and SDAIA's mandate provide governance anchors,



but operationalizing ethical AI at the clinical frontline requires ongoing investment in training and institutional culture.

Incremental PHM Gains vs. Transformational AI Ambition: Vision 2030 articulates transformational healthcare objectives. Population health improvement occurs incrementally — quarterly screening targets, HbA1c uptake percentage points. Managing expectations around AI's contribution — avoiding both unrealistic optimism and premature skepticism — constitutes a critical leadership challenge.

4.5 Implications for Policy and Practice

4.5.1 For National Policymakers (CHI, MOH, Health Holding Company, SDAIA)

5. Complete the Policy Cascade: Develop and disseminate detailed implementation guidance, standard operating procedures, and toolkits. Explicitly integrate AI deployment protocols within PHM policy guidance.

6. Establish Dedicated PHM and AI Financing: Create explicit budget lines, capitation adjustments, or outcome-based payments that resource both PHM activities and AI infrastructure. QHC's experience of "no specific budget" is unsustainable.

7. Strengthen Technical Support Infrastructure: Invest in regional PHM technical support units providing on-demand analytics, AI implementation coaching, and problem-solving assistance.

8. Develop National PHM and AI Workforce Strategy: Commission competency framework development, accredited training programs, and career pathways for PHM roles and AI-enabled clinical functions.

9. Mandate PHM Maturity Assessment with AI Readiness Dimension: Implement annual PHM maturity assessment including AI infrastructure readiness, enabling national progress tracking.

10. Establish Ethical AI Governance for Healthcare: Develop specific ethical AI guidelines for clinical PHM applications, building on SDAIA's national framework to address algorithmic bias, data privacy, and patient consent.

4.5.2 For Health Clusters and Providers

11. Invest in PHM and AI Governance: Designate PHM Champions with protected time. Establish AI champion roles alongside clinical PHM leadership.

12. Build Data Capacity for AI-PHM Integration: Develop or acquire capability to process segmentation outputs, conduct local risk stratification, and feed AI models with local clinical data.

13. Implement Change Management for AI Adoption: Treat workforce resistance to AI as predictable. Develop structured change management approaches including AI literacy training, clinical champion programs, and iterative feedback mechanisms.

14. Pilot AI Tools Systematically: Select AI tools with demonstrated evidence bases, pilot in defined populations, measure impact against PHM indicators, and scale based on evidence.

15. Document and Share AI-PHM Learning: QHC's implementation learning model should be extended to AI deployments — capturing what worked, what failed, and why.

4.5.3 For Payers (Insurance Companies)

16. Integrate PHM and AI into Core Business: Transition from claims processing to population health stewardship, leveraging AI analytics for population segmentation and risk-based contracting.

17. Collaborate with Providers on AI-Enhanced Risk Stratification: Invest in AI-powered payer-provider shared risk stratification platforms.

18. Align Payment with PHM Objectives: Develop payment models that reward screening, risk stratification, care coordination, and outcome achievement.

19. Support Provider PHM and AI Capacity: Provide technical assistance, AI analytics support, and implementation resources to contracted providers.

4.6 Limitations

This review has several limitations. First, it is based on four core documents plus supporting references; additional unpublished implementation experiences may exist. Second, the Qassim implementation study reports early outcomes (Q1–Q3 2024) of a 5-year strategic plan; longer-term follow-up is required. Third, the CHI Guidebook focuses on the private insurance sector; specific public sector implementation guidance may differ. Fourth, the AI review by Karrar et al. (2025) is a narrative review, which may not capture all relevant AI evidence. Fifth, our synthesis cannot establish causal attribution of



population health outcomes to PHM or AI interventions.

4.7 Future Research Directions

20. Longitudinal PHM Outcome Studies: Track PHM implementation across Saudi health clusters over 3–5 years, measuring both process and outcome indicators.

21. AI-PHM Integration Evaluation: Conduct rigorous evaluation of AI tool deployments within Saudi PHM programs, measuring impact on PHM cycle efficiency, clinical decision quality, and population health outcomes.

22. Comparative Implementation Effectiveness: Compare PHM implementation approaches across clusters to identify context-strategy-outcome relationships.

23. Economic Evaluation of AI in PHM: Conduct cost-effectiveness and ROI analyses of AI PHM interventions in Saudi settings, including HMIS AI deployments.

24. Patient and Community Perspectives: Investigate patient, family, and community experiences of AI-enabled PHM programs, including digital equity and access concerns.

25. Health Equity Impact Assessment: Systematically evaluate PHM and AI effects on health disparities across nationality, gender, geographic region, and socioeconomic status.

26. PHM and AI Workforce Development: Investigate optimal competency frameworks, training modalities, and career structures for emerging PHM-AI roles in the Saudi context.

5. CONCLUSION

Saudi Arabia stands at a pivotal moment in its health system transformation journey. Population Health Management has transitioned from theoretical concept to operational framework to implemented reality. The CHI Population Health Management Guidebook provides a robust, contextually-adapted national framework. The Qassim Health Cluster implementation demonstrates that systematic PHM is achievable within existing infrastructure, while revealing critical gaps requiring systemic attention.

Critically, this review demonstrates that Artificial Intelligence is not a peripheral technological add-on to PHM — it is becoming its operational infrastructure. AI's capabilities in population segmentation,

predictive risk stratification, clinical decision support, patient engagement, and HMIS management map directly onto every step of the CHI PHM cycle. Saudi Arabia's national AI investments — from SDAIA's governance mandate to KAUST's Mini GPT-Med, to the USD 40 billion technology fund — create a national enabling environment unmatched in the region for AI-enabled PHM transformation.

The Saudi PHM experience offers four broader lessons for global health systems pursuing population health transformation. First, foundational health system investments precede and enable successful PHM implementation — PHM cannot be layered onto weak systems. Second, AI accelerates PHM capability when built on robust data infrastructure and governance frameworks; without these foundations, AI deployment risks exacerbating existing inequities. Third, policy frameworks require continuous refinement through implementation feedback loops — the gap between national AI policy and local clinical implementation is inevitable and must be actively managed. Fourth, PHM and AI implementation develop organizational capabilities — analytical, relational, strategic, digital — that extend beyond the immediate intervention.

For Saudi Arabia, realizing Vision 2030's healthcare aspirations requires sustained commitment to both PHM scaling and responsible AI integration. This demands policy completion, dedicated financing, AI governance frameworks, technical support infrastructure, culturally sensitive workforce development, and systematic learning across 20 health clusters. The foundation is laid; AI infrastructure is being built; early evidence is encouraging. With continued investment, learning, and adaptation, AI-enabled Population Health Management can deliver on its promise: a more sustainable, equitable, and effective healthcare system for all residents of the Kingdom.

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Supplementary Materials

Supplementary Table S1: Detailed Comparison of International PHM Frameworks
Supplementary Table S2: CHI PHM Guidebook Intervention Menu with Evidence Ratings
Supplementary Table S3: Qassim Health Cluster PHM 5-Year Strategic Plan Components
Supplementary Table S4: AI Applications in Saudi Healthcare — Comparative Evidence Summary
Supplementary Figure S1: PRISMA Flow Diagram
Supplementary Appendix A: Data Extraction Framework