Transform Health
MEXICO

Guide of Digital Transformation and Interoperability in Health

In Mexico

Digital transformation– The comprehensive process by which an organization adopts digital technologies to redesign their business models, optimize their processes, improve the user experience and strengthen their ability to adapt to a constantly changing environment.

Interoperability– The capacity of different applications, systems, organizations and devices for exchanging information effectively, safely and frictionlessly, without the need of additional intervention or loss of meaning.

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— David Soto

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I. Context and Vision

Introduction

The digital transformation and interoperability of health systems offer a crucial opportunity to accelerate progress toward universal health coverage by expanding population coverage, especially to underserved and marginalized communities, improving service coverage, and reducing the cost of care. When developed and implemented ethically and equitably, digital health can improve the delivery, quality, and efficiency of care. It can enable more effective systems integration, including continuity of care at all levels, drive evidence-based decision-making, reduce redundancies and errors, facilitate better coordination, and optimize management.

This guide presents a strategic path and a framework for action for digital transformation and interoperability in healthcare in Mexico. Its purpose is to lay the foundation for a connected and secure healthcare ecosystem, overcoming the historical fragmentation that has limited the quality, efficiency, equity, and accessibility of care.

The scope of this guide is national and covers all stakeholders in the National Health System, including federal and state public institutions, as well as the private sector. It proposes an interoperability model that allows for the fluid and secure exchange of information to ensure continuity of care, regardless of where or by whom a person receives care.

This document is intended for a broad audience of stakeholders whose collaboration is essential for the success of digital transformation. This includes:

- ➔ Decision-makers and legislators at the federal, state, and municipal levels.
- ➔ Directors and administrative staff of public (IMSS, ISSSTE, IMSS-Bienestar, PEMEX, SEDENA, SEMAR, Ministry of Health) and private health institutions.
- ➔ Healthcare professionals (physicians, nurses, pharmacists, laboratory technicians, engineers, administrative staff) who interact directly with patients and information systems.
- ➔ Technology developers, academia, and civil society involved in the creation, implementation, and oversight of digital health solutions.
- ➔ Nonprofit organizations, patient organizations, and the general public, as the ultimate beneficiaries and owners of your health information.

Overview of the Health System

By 2025, the Mexican healthcare system has shown scattered progress in digitalization (IMSS, IMSS-BIENESTAR, ISSSTE, PEMEX, and SEDENA with ECE implementation >100%), but only 36.3% of medical units have adopted electronic medical records; at the primary level, coverage is just 34.3%. The predominance of heterogeneous systems and isolated developments has led to a proliferation of clinical data silos, a lack of continuity of care, and limited use of population information for management and prevention.

Main Challenges

- Information silos and low interoperability between institutional systems and the private sector.
- Persistence of paper-based processes in consultations, pharmacies, laboratories and clinical archives.
- Historical absence of a unique identifier and national standardization of patient, provider, and organization data, although in 2025 the CURP and biometrics will begin to consolidate as cross-cutting mechanisms.
- Gaps in connectivity, digital infrastructure, and technical capabilities are exacerbated in rural and marginalized areas and small private clinics.
- Concerns about privacy and the protection of sensitive data in the face of recent cyberattacks and the centralization of electronic records.

Regulatory Context

The current regulatory framework is a patchwork of general laws and Mexican Official Standards (NOMs) that, while laying some groundwork, are misaligned and insufficient for the modern digital ecosystem. Crucial standards such as NOM-024-SSA3-2012, which regulates electronic medical records, are technologically outdated and do not include modern standards such as HL7 FHIR. This lack of harmonization between health regulations, data protection laws, and interoperability standards creates legal uncertainty and hinders innovation.

However, there are initial efforts that pave the way for change:

- Existence of initial regulatory frameworks: NOM-024-SSA3-2012, NOM-035-SSA3-2012, LFPDPPP (Personal Data Protection Law) and digital reforms to the General Health Law.
- Recent development of the Digital Health Card, biometric CURP, and MX Key as pillars of digital identity, aligning with other ecosystems.
- Strong political impetus for the creation of the Universal Health System 2026, proposing national interoperability, a single electronic file, and a centralized digital credential that connects IMSS, ISSSTE, and IMSS-Bienestar.

Vision and Objectives

Build an interoperable, scalable, and secure national digital health ecosystem, optimizing the quality of care, strengthening citizen trust, promoting equity, ensuring data protection, and facilitating innovation, all for the benefit of public health and well-being.

Guiding principles (fairness, security, interoperability, scalability)

The transformation will be guided by a set of ethical and operational principles, based on the Health Data Governance Principles, to ensure that technology serves the well-being of people:

- Protecting people: Recognizing that health data is an extension of the person, ensuring informed consent, comprehensive security, transparency, and minimization of data collection.
- Promoting value in health: Using data ethically to improve clinical outcomes, enable responsible research, optimize system efficiency, and strengthen epidemiological surveillance.
- Prioritize equity: Design inclusive digital services that reduce access gaps, ensure cultural relevance, and guarantee a fair distribution of the benefits of digitalization.

Additionally, the target system will be characterized by being:

- Person-Centered: The patient is the owner and manager of their data.
- Interoperable: Systems communicate through a common technical and semantic "language."
- Secure and Reliable: Robust data protection with complete transparency in its use.
- Scalable and Sustainable: An architecture that can grow and adapt, with a financing model that ensures its long-term viability.

II. Governance and Strategy

Governance Model

To overcome the historical fragmentation of the Mexican National Health System, a governance model of lean and efficient coordination is proposed. This model seeks to balance three critical dimensions:

1. The national leadership of the Health Sector in matters of digital health.
2. The operational autonomy of public institutions and federal entities.
3. Collaborative participation of the private sector, academia and civil society.

Avoiding the creation of new, costly bureaucratic structures and strengthening the capacities of existing organizations. This approach is consistent with international recommendations on inclusive and sustainable digital transformation.

Map of Actors (Public, Private, Academia, NGOs, Citizens)

The success of digital transformation depends on the coordinated collaboration of a diverse ecosystem of stakeholders. The governance model must be inter-institutional and multi-sectoral, with equitable representation of the following groups:

Federal Public Sector

- Ministry of Health: General political leadership of the national digital health ecosystem.
- Ministry of Finance and Public Credit: Budget oversight and financial sustainability.
- Secretariat of Infrastructure, Communications and Transportation: National connectivity infrastructure, including access in rural areas.
- Coordination of the National Digital Strategy (Digital Transformation and Telecommunications Agency): Articulation with transversal digital agendas (Llave MX,).
- General Directorate of Health Sector Modernization: It will act as the national technical secretariat, responsible for issuing technical guidelines, developing standards (including the FHIR Mexico Implementation Guides), system certification, and research.
- General Directorate of Health Information: It will assume operational coordination, including management of the National Interoperability Platform (PNI) infrastructure, sectoral cybersecurity, and support for federal entities.

Federative Entities

Representatives from state health ministries responsible for territorial implementation and adaptation of national policies to the local context, with an emphasis on equity and access in highly marginalized municipalities.

Health Institutions

Public Sector: Executives from IMSS, ISSSTE, IMSS-Bienestar, PEMEX, SEDENA, and state health services.

Private Sector: Executives of private hospitals, clinics, laboratories, pharmacies, private insurance companies, startups, and technology providers.

Academia

Universities and research centers in digital health, public health, medical informatics, software engineering, and cybersecurity, providing technical knowledge, innovation, and the training of specialized talent.

Civil Society and Citizenship

Non-governmental organizations (NGOs) focused on health, human rights, equity, the digital divide, transparency, and access to information.

Representatives of patient associations and community groups, to ensure that digital solutions are user-centered, accessible, and strengthen the legitimacy of the system.

Institutional Roles and Responsibilities

National Digital Health Council

The creation of a National Digital Health Council is proposed as a governing body with a tripartite composition:

40% Federal Sector: Representatives of SSA, SHCP, SCT, RENAPO, ATD.

30% Subnational Sector and Social Security: Representatives of federal entities, IMSS, ISSSTE, IMSS-Bienestar, etc.

30% Non-governmental actors: Academia, private sector, NGOs, patients.

This composition ensures inclusive and balanced decision-making, mitigating regulatory capture and promoting innovation.

Key Institutions and their Functions

Ministry of Health (SSA)

- Exercises general political leadership over the digital health ecosystem.
- Approves national guidelines, standards and policies.

Directorate General for the Modernization of the Health Sector (DGMoSS)

- It acts as the national technical secretariat (replacing CENETEC functions since 2023).
- Issues technical guidelines, develops standards and Implementation Guides.
- Manages the certification of systems in compliance with national and international standards.

General Directorate of Health Information (DGIS)

- It operationally coordinates the National Interoperability Platform (PNI).
- Manages data infrastructure, sectoral cybersecurity, and support for federal entities.
- Oversees the integrity of SINBA and SINAIS.

RENAPO (National Population Registry)

- Provides identity services based on biometric CURP.
- Ensures demographic synchronization and multi-factor authentication for the "e-Salud CURP" ecosystem.

COFEPRIS (Federal Commission for Protection against Health Risks)

- Issues guidelines for electronic prescriptions.
- Supervises its verification and validity at dispensing points.

III. Legal and Ethical Frameworks: Data Governance, Consent, Privacy

The ju frameridiculousand ethical is the fundamental basis for generating public trust in the system, protecting citizens' rights, and ensuring the responsible use of health data.

Data Governance

Health data governance is governed by:

- General Health Law (LGS): Fundamental framework that recognizes the right to health and the confidentiality of clinical information.
- Federal Law on the Protection of Personal Data Held by Private Parties (LFPDPPP): Applicable to the private sector.
- General Law on the Protection of Personal Data Held by Obligated Subjects (LGPDPPSO): Applicable to the public sector.
- NOM-004-SSA3-2012: Electronic medical records.
- NOM-024-SSA3-2012: Electronic health record information systems.
- Health information exchange.

Principles of Governance

- Security and Confidentiality: Technical encryption controls (AES-256), role-based access control (RBAC), and immutable auditing.
- Traceability: Immutable record of each access, consultation, and modification of clinical data, allowing for subsequent auditing.
- Privacy by Design: Incorporating privacy protections from the initial stage of system design.

Informed Consent

A granular and dynamic informed consent model is established, allowing the patient to:

- Define what specific data you share (diagnoses, medications, imaging studies, clinical notes, etc.).
- Specify who you share with (other providers, specific public institutions, researchers).
- Determine the specific purpose of each sharing: (1) primary care, (2) public health and surveillance, (3) research, (4) clinical management.
- Revoke consent at any time.

Enhanced Mechanisms for High-Risk Consent

- Acts involving sensitive data (HIV diagnoses, mental health, reproduction) require an advanced electronic signature.
- Suppliers must periodically (every 12 months) confirm consent to access sensitive data.

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Collective Consent and Research

- Secondary use of data with collective consent is permitted for public health, population research, and precision medicine, provided that anonymization is applied and ethical principles of equity and non-discrimination are adhered to.

Privacy and Patient Rights

The Patient's Digital Rights are codified:

1. Property Rights: The patient is the owner of his or her clinical data.
2. Right of Access: Free access to your complete file through the health portal.
3. Right to Portability: Obtain a copy of your information in a standard and interoperable format (FHIR JSON).
4. Right to Understandability: Clear explanation of how your information is used.
5. ARCO Rights: Rights ofAccess, Rectification, Cancellation and Opposition
6. Right to Object: Reject secondary uses of data, except in cases of serious public health.

Figure of the Digital Patient Advocate:

To guarantee the exercise of these rights, the creation of the Digital Patient Advocate is proposed, an entity attached to the National Health System with the following functions:

- Guidance and advice on digital rights.
- Mediation in conflicts between patients and institutions.
- Defense of rights against privacy violations.

Policy and Strategic Framework

The national strategy is articulated around a 2030 Vision for a Health System that "navigates with you"—one that is person-centered, equitable, resilient, and enabled by digital interoperability. Implementation will be carried out through a phased roadmap, designed to deliver early clinical value and mitigate the risks of large-scale implementation.

Phase I: Foundations and Pilots

Goals:

- Establish governance, technical infrastructure and regulatory frameworks.
- Demonstrate viability through pilots in key institutions.
- Publish national reference standards.

Key Milestones:

1. Launch of the Minimum Viable Product (MVP) of the National Interoperability Platform (PNI):
    - Deployment of API Gateway for initial connection of IMSS, ISSSTE, IMSS-Bienestar, and others.
    - Implementation of Master Patient Index (MPI) services and organization registration.
2. Publication of National Standards:
    - Beta version of the Interoperability Implementation Guide, including profiles for critical resources: Patient, Observation, Medication, MedicationRequest, DiagnosticReport, Encounter.
    - Official mappings between local terminologies and SNOMED CT, LOINC, RxNorm, etc.
3. Citizen Portal "My Health Mexico":
    - Beta version of the portal that allows citizens to access their interoperable file.
    - Download data in FHIR format.
    - Granular consent management.
4. Regulatory Initiatives:
    - Preparation of drafts for the update of NOM-024-SSA3-2012.
    - Publication of pilot guidelines for interoperable electronic prescriptions.

Phase II: National Escalation and Value Cases

Goals:

- Expand the PNI to all federal entities.
- Demonstrate cases of clinical value and operational impact.
- Ensure technical and financial sustainability.

Key Milestones:

1. Expansion of the PNI:
    - Connection of the 32 federal entities to the ecosystem.
    - Integration of private health institutions.
    - Implementing secure connectivity in rural areas using alternative models (offline-first, asynchronous synchronization).
2. National Electronic Prescription (Phase 1):
    - Operational launch of interoperable electronic prescription.
    - Integration with public and private pharmacies.
    - Tracking medicines through the supply chain.
3. Telemedicine Integration:
    - Connecting telemedicine platforms with the Electronic Medical Record (EMR).
    - Standardized protocols for remote consultations and referrals, including them in the SS PRONAM.
4. Sectoral Cybersecurity:
    - Establishment of a 24/7 sector-wide Security Operations Center (SOC).
    - Implementation of cybersecurity standards (NIST CSF 2.0, ISO 27001).

Phase III: Consolidation, Analytics and Maturity

Goals:

- Achieve universal national coverage.
- Enable population analytics and epidemiological surveillance.
- Ensure maturity in data governance and cybersecurity.

Key Milestones:

1. Full Coverage:
    - Integration of the public sector and massive participation of the private sector.
    - Single medical record accessible from any point of care within the country.
2. Federated Data Lake:
    - Federated architecture for population analysis, without centralizing sensitive personal data.
    - Enabling AI/ML analytics for disease prediction, resource management, and health equity.
    - Real-time epidemiological surveillance integrated with public health.
3. Electronic Prescription (Phase 2):
    - Extension of electronic prescriptions to controlled medications.
    - Integration with national pharmacovigilance systems.
4. Cybersecurity Maturity:
    - Consolidation of the sector at the NIST CSF 2.0 Tier 3 level.
    - Annual external audits and ISO 27001 certification for all participating institutions.

Financing and Sustainability Models

Investment Projection:

A total cumulative investment of 47.35 billion Mexican pesos (approximately 2.631 billion USD, or ~US$328 million/year) is projected for the 2025-2030 period. This amount is considered consistent with international standards, representing less than 25% of health spending over the next five years.

Investment Distribution by Components:

Component	Investment (MXN Billions)	Percentage	Description
Technological Component	33,600	71%	PNI, institutional integration, citizen portal, connectivity, cybersecurity, infrastructure.
Human Component	10,600	22%	Mass training (500,000+ professionals), technical teams, change management
Regulatory Component	3,150	7%	Regulatory development, certification, legal advice

Data Governance Principles

Health data management will be governed by a set of principles designed to protect people, generate value for the health system, and promote health equity.

Health Data Lifecycle

Harvest

- It must be carried out for a defined, legitimate and explicit purpose, under the principle of data minimization.
- Prior patient consent, except in public health emergencies.
- Documentation of source and data quality.

Storage and Processing

- Ensure robust security through encryption (AES-256 for data at rest; TLS 1.3+ in transit).
- Role-based access control (RBAC) and the principle of least privilege.
- Backup and disaster recovery systems (RTO <4 hours, RPO <1 hour).

Exchange and Use

- Enabled through the National Interoperability Platform with open standards (FHIR, HL7, IHE).
- Primary uses: clinical care, continuity of care.
- Secondary uses: public health, research, epidemiological surveillance, with anonymization safeguards.

Conservation and Disposal

- Mandatory anonymization for secondary uses after clinical retention period.
- Secure procedures for the destruction of non-reusable data, with documented audit trails.

Principios FAIR (Findable, Accessible, Interoperable, Reusable)

Although the acronym "FAIR" is not explicitly used in Mexican legislation, the principles of this guide are closely aligned with this international framework, recognized by UNESCO and global scientific organizations:

Findable

- Architecture with centralized directories and metadata for efficient location of clinical information.
- Unique identifiers (biometric CURP) that facilitate searching and linking patient records.
- Semantic indexing systems with SNOMED CT, LOINC, RxNorm.

Accessible (Accesible)

- The patient's constitutional and legal right to access their complete medical record through the health portal.
- Obligation of systems to provide information in readable formats (FHIR JSON/XML, PDF, PDF/A).
- Access to authorized healthcare professionals in accordance with consent and clinical role.
- Compliance with accessibility standards for people with disabilities (WCAG 2.1 AA).

Interoperable (Interoperable)

- Data standards: HL7 FHIR (primary), HL7 v2.x (transition), CDA (documents).
- Terminologías: SNOMED CT, ICD-11, LOINC, RxNorm, CVX.
- Perfiles: IHE (XDS, PIX, RRE, EPCS, LRI), HL7 CCDA, FHIR Structured Data Capture (SDC).
- Technical, semantic, organizational and legal interoperability.

Reusable

- Framework established for secondary use of anonymized data through "public interest licenses" for research and public health.
- Collective consent for community data, promoting ethical reuse.
- Nationally accessible research records.

Data Quality, Custody and Accountability

Data Quality will be promoted through:

1. Standard Terminologies: Mandatory use of SNOMED CT, LOINC, RxNorm in national catalogs.
2. Official Mappings: Semantic mappings between legacy local systems and standard terminologies, managed by DGMoSS.
3. Automatic Validations: Validation rules at capture time (range of values, valid clinical combinations).
4. Quality Audits: Quarterly audits of data completeness, accuracy, and consistency.

Data Custody (Stewardship)
Governance defines clear roles of responsibility:

- DGMoSS and DGIS: Custodians of standards, national infrastructure, interoperability and cross-cutting security.
- Health Institutions (IMSS, ISSSTE, SSA, etc.): Responsible for the quality, security and confidentiality of the data they generate and safeguard.
- Patients: Custodians of their personal information, with the right to control what data they share and with whom.

Accountability
It is established through multiple mechanisms:

1. Traceability:
    - Each access, consultation and modification in the Electronic Medical Record must be recorded immutably.
    - Periodic audit in accordance with NOM-004-SSA3-2012.
    - Data protection audit supervised by DGMoSS.
2. Transparency:
    - Publicly accessible National Interoperability Dashboard with performance metrics.
    - Annual publication of cybersecurity, incident, and regulatory compliance audit reports.
    - Report security breaches within 72 hours.
3. Supervision:
    - The corresponding secretariats and institutions.
    - Digital Patient Advocate: Defense of digital rights and conflict mediation.
    - External Audit: Annual independent cybersecurity and compliance audits (ISO 27001, SOC 2).

VI. Architecture and Interoperability

Transition from the Isolated Systems Model to a Connected Ecosystem:
The proposed national architecture represents a fundamental transition from a fragmented model of isolated information systems to a connected, secure, and person-centered digital health ecosystem. It is based on a federated approach that respects the autonomy of public, private, and specialized institutions, but requires mandatory compliance with national and international standards to ensure the smooth, secure, and meaningful flow of clinical information.

This paradigm shift seeks to:

- Continuity of care: Access to clinical records throughout the patient's life cycle.
- Operational efficiency: Elimination of duplications, process automation.
- Security and privacy: Protecting sensitive data through encryption, auditing, and consent.
- Equity: Reducing gaps in access to information between urban and rural areas, public and private institutions.

Logical Architecture Diagram: Reference Layers

The reference architecture is structured into four logical layers that organize components, functions, and interactions in a coherent and scalable manner:

User Layer:

It includes the final actors that interact with the ecosystem:

- Patients/Citizens: Access through the health portal to view their records, manage consents, download information, and request portability.
- Healthcare Professionals: Doctors, nurses, specialists, and laboratory technicians access the system through institutional systems (EHRs) or mobile applications.
- Administrators: Responsible for information systems, regulatory compliance, security auditing.
- Researchers: Access to anonymized data for research under ethical frameworks and collective consent.

Application Layer:

Contains the health information systems of each institution and vertical applications:

- Institutional Electronic Medical Record (ECE): Each institution (IMSS, ISSSTE, IMSS-Bienestar, private hospitals) maintains its ECE operational.
- Specialized Departmental Systems: Laboratory (LIS), Imaging (PACS), Pharmacy (Pharmaceutical Management System).
- Remote Care Applications: Telemedicine, remote monitoring of chronic patients.
- Health Portal: Web and mobile access interface for citizens.
- Third-Party Systems: Assisted diagnosis applications, medication management, allergy tracking.

All of these applications consume and expose data through the interoperability layer using standardized APIs.

Data and Interoperability Layer (Architectural Core)

It is the heart of the architecture. It contains critical orchestration and integration components:

- National Interoperability Platform (PNI):
    - Integration bus that orchestrates secure data exchange.
    - API Gateway REST basado en HL7 FHIR R4.
    - Intelligent request routing based on patient affiliation and consent.
    - Centralized transaction management and immutable auditing.
- National Master Patient Registry (NMPR):
    - Based entirely on CURP as a unique identifier.
    - Master Index (MPI) that synchronizes demographic data.
    - Critical metadata: allergies, blood type, organs for donation, emergency contacts.
    - Link with RENAPO for identity validation and biometric authentication.
- Centralized Terminology Services:
    - Mappings between local terminologies and standards (SNOMED CT, LOINC, RxNorm, ICD-11, CVX).
    - National catalogs of medicines, procedures, diagnostic codes.
    - Regular updates synchronized with international updates.
- Consent Management:
    - Granular consent engine that evaluates permission for each transaction.
    - Audit of consents granted and revoked.
- Security and Identity Service:
    - Authentication using OAuth 2.0/OpenID Connect (OIDC).
    - Biometric and multifactor validation (CURP + SMS/email).

    - Secure session and token management.

Infrastructure Layer

Composed of the basic technological resources that support all the upper layers:

- Network Connectivity:
    - National connectivity infrastructure (fiber optics, microwaves, alternative technologies in remote areas).
    - Virtual private networks (VPNs) for secure transit of sensitive data.
    - Compliance with 99.9% availability service level agreements (SLAs).
- Computing Services:
    - Cloud infrastructure (AWS, Cloud, or national solution) for scalability and elasticity.
    - FHIR servers operated by DGMoSS/DGIS for PNI and RMNP.
    - Geographically distributed redundant storage for resiliency.
- Databases:
    - Relational databases (PostgreSQL, Oracle) for transactional data.
    - Data lakes for analytics and big data.
    - Document storage (S3/Azure Blob) for DICOM images, PDFs.
- Security and Identity:
    - Hardware security modules (HSM) for key management.
    - Digital certification (PKI/X.509) for electronic signatures.
    - 24/7 Security Operations Center (SOC) for threat monitoring.
    - Firewalls, IDS/IPS, WAF (Web Application Firewall).

National Health Information Exchange (HIE) Model

Fundamentals of the Mexican HIE Model:

The national health information exchange (HIE) model is based on an adaptation of the Open Health Information Exchange (OpenHIE) framework, developed by the Health Information Systems Program (HISP) at the University of Oslo and widely adopted in lower-middle-income countries such as Uganda, Kenya, Bangladesh, and India.
The model does not centralize all clinical data in a single national repository (thus avoiding the concentration of privacy and security risks), but rather creates a shared, federated infrastructure that facilitates secure exchange between each institution's existing decentralized systems.

CURP-Centric Architecture: The Pillar of Digital Identity in Health

A fundamental strategic architectural decision is that all components operate in a "CURP-native" manner, that is, the Unique Population Registry Key is the mandatory identifier in each transaction:[10,11]
Advantages of this approach:

- Nearly universal coverage: 95% of the Mexican population has a CURP.
- Existing infrastructure: Leverage RENAPO, avoiding the need to create a new identity system.
- Reduced cost: Implementation is 70% less expensive than creating a new unique health identifier.
- Accelerated time: 18 months of adoption vs. 5 years of a new system.
- Cross-cutting integration: The CURP is already used by the SAT (RFC), Llave MX, educational institutions, and banks.

Central Components of the Mexican HIE

1. National Master Patient Registry (NMPR)

Definition and Function:
The RMNP functions as the national Master Patient Index (MPI), based entirely on CURP as the primary unique identifier.

Architecture:

- Demographic Synchronization Layer: Real-time linking with RENAPO for identity validation, updated demographic data (name, date of birth, address, marital status).
- Critical Clinical Metadata Layer:
    - Known allergies (coded in SNOMED CT)
    - Blood type and compatibility
    - Organs suitable for donation

        - Identified chronic medical conditions
        - Emergency contacts and powers of attorney for health
    - Duplicate Management and Identity Merging:
        - Deduplication rules based on probabilistic algorithms (Soundex, Jaro-Winkler) applied to demographic data.
        - Target <1% residual duplicates.
        - Procedure for merging temporary identifiers (assigned in emergencies without connectivity) within <7 days.

Security:

- Access restricted to authorized personnel with specific roles (demographic data readers, allergy writers, administrators).
- AES-256 encryption for data at rest.
- Immutable auditing of access and modifications.

2. National Interoperability Platform (PNI)

Definition and Function:
The PNI is the central integration bus that orchestrates the exchange of information between heterogeneous systems, ensuring security, standards compliance, and availability.

Technical Architecture:

- API Gateway REST/FHIR:
    - Endpoints exposed for CRUD (Create, Read, Update, Delete) operations on FHIR resources.
    - Base route: https://api.pni.gob.mx/fhir/r4/
    - Examples of endpoints:
        - GET /Patient/{curp} → Get demographic data.
        - GET /Observation?patient={curp} → Get observations (labs, vitals).
        - POST /MedicationRequest → Create medication request.
        - GET /DiagnosticReport?patient={curp}&date=after:{date} → Get recent reports.
- Smart Routing:
    - Check the patient's affiliation in the RMNP.
    - Identify institutions where the patient has records.
    - Validates patient consent to share specific data.
    - Routes the request to the source systems (IMSS, ISSSTE, private clinics, laboratories).
    - Aggregates responses and returns consolidated information to the requester.
- Exchange Pattern: Modified Hub-and-Spoke (OpenHIE):

    - Hub: PNI as a central routing point.
    - Spokes: Institutional ECEs that expose their own FHIR APIs.
    - Each institution maintains control of its data, but agrees to expose standards-compliant APIs.
- Transaction Orchestration:
    - Handling long-running transactions (queries to multiple institutions can take seconds).
    - Automatic retries in case of destination failure.
    - Configurable timeout (default 30 seconds).

Advanced Features:

- Distributed Cache: For frequently accessed data (e.g., active medications, allergies).
- Event Streaming (Apache Kafka): For real-time notifications of clinical events (e.g., emergency room admission, hospital discharge).
- FHIR Conformance Validation: Each response is validated against FHIR-MX profiles before being returned.

Security:

- System-to-system authentication using mTLS (mutual TLS) certificates.
- User authentication using OAuth 2.0/OIDC with biometrics.
- Rate limiting and throttling to prevent abuse.
- Complete audit of all transactions to detect unauthorized access.
- End-to-end encryption of sensitive data.

3. Health Portal

Portal Vision:
It is the citizen interface of the ecosystem, allowing each person to access their longitudinal inter-institutional file, exercise control over their data, and actively participate in their care.

Main Features:

1. Access to the Interinstitutional File:
    - Consolidated display of:
        - Medical history (diagnoses, surgeries, hospitalizations)
        - Active medications from all institutions
        - Known allergies
        - Recent labs and imaging studies
        - Vaccinations
        - Disabilities and chronic conditions
    - Chronological view of all queries made.

2. Granular Consent Management:
    - Visual dashboard where the patient can see which institutions/professionals have access to which data.
    - Data type controls: "Allow [Institution X] to access my diagnoses until [Date]"
    - Instant revocation of permits.
    - History of consents granted and revoked with timestamps.
3. Data Portability:
    - Download the complete file in formats:
        - FHIR JSON/XML (standard)
        - PDF legible
        - CSV for personal analysis
    - Secure transfer to another healthcare provider using digital referral letters.
4. Two-Way Communication:
    - Notifications of new laboratory results.
    - Alerts for medications pending refill.
    - Reminders of expired vaccines.
    - Secure messaging with healthcare providers.

Strong Authentication (Multi-Factor):

- Factor 1: CURP (knowledge)
- Factor 2: Biometrics (fingerprint, iris) captured in RENAPO or sent via facial verification in the app.
- Factor 3: OTP (One-Time Password) via SMS or email.
- Result: JWT token valid for 8 hours; renewal requires re-authentication.

Compliance with Standards:

- WCAG 2.1 AA for accessibility (people with visual, hearing, and motor disabilities).
- Available in Spanish, with translation options into indigenous languages (Mixe, Zapotec, Mayan, etc.) in future phases.
- Responsive design for mobile devices (where access is concentrated in rural areas).

Interoperability Framework: Four Levels

For information exchange to be effective and meaningful, interoperability must be addressed systematically at four interdependent levels, as defined by international reference frameworks (OpenHIE, IHE, PAHO-DTCI).

Level 1: Technical Interoperability

Objective: Ensure that systems can physically connect and transfer data without errors.
Components:

1. Communication Protocols:
    - HTTPS (TLS 1.3+): Mandatory secure transport protocol.
    - REST (Representational State Transfer): API architecture for resource exchange.
    - FHIR RESTful APIs: Standard HTTP methods (GET, POST, PUT, DELETE) for CRUD operations.
2. Data Formats:
    - JSON (JavaScript Object Notation): Primary format, lighter and more manageable.
    - XML (eXtensible Markup Language): Alternative format for legacy compatibility.
    - Validation against FHIR schema to ensure correct structure.
3. Network Connectivity:
    - National connectivity infrastructure (fiber optics, 4G/5G mobile networks).
    - Alternatives for areas without connectivity (offline synchronization, asynchronous models).
    - VPNs to encapsulate sensitive traffic.

Success Metrics:

- API response time: <2 seconds (p95)
- System availability: ≥99.9%
- Successful transaction rate: ≥99.5%

Level 2: Semantic Interoperability
Objective: To ensure that the meaning of the exchanged data is understood identically by all systems.
Components:

1. Standardized Clinical Terminologies:
   - SNOMED CT (Systematized Nomenclature of Medicine - Clinical Terms):
     - Comprehensive clinical terminology with >350,000 concepts.
     - Used for diagnoses, procedures, findings, symptoms.
     - Nationally licensed through agreement with SNOMED International.
   - LOINC (Logical Observation Identifiers Names and Codes):
     - Codes for ~90,000 lab tests and observations.
     - Used in all laboratory information systems.
   - RxNorm (Medication Naming System):
     - Standard nomenclature for medications, doses, forms, routes.
     - Used in prescription and pharmacotherapy systems.
   - ICD-11 (International Classification of Diseases, 11th Revision):
     - Statistical classification of diseases, injuries, health problems.
     - Progressive implementation from ICD-10, with target date 2027.
   - CVX (Vaccine Code Set):
     - Standardized codes for vaccines.
     - Mandatory integration into immunization records.
2. National Catalogs:
   - Medicines authorized in Mexico (COFEPRIS).
   - Health procedures and services.
   - Registered Health Establishments (CLUES - Unique Key for Health Establishments).
   - Health professionals with a valid professional license.
3. Semantic Mappings and Conversions:
   - Equivalence tables between legacy and standard local terminologies.
   - Automatic algorithms for real-time translation during exchanges.
   - Periodic (semi-annual) review of mappings by teams of clinical experts.

Success Metrics:

- 95%+ of data encoded in standard terminologies.
- <1% of semantic ambiguities detected in audits.
- Mapping accuracy: >99%.

Level 3: Organizational Interoperability

Objective: To coordinate processes and workflows between different institutions to ensure continuity and efficiency of care.

Components:

1. Standardization of Key Processes:
    - Referral and Counter-Referral: IHE Standards (Referral Requests and Follow-Up - RFD).
    - Laboratory Results: IHE Laboratory (LAB) Standards for order and result.
    - Imaging: IHE Radiology (RAD) Standards for Report and Image Sharing.
    - Electronic Prescription: Standardized process of prescription, transmission, dispensing.
2. Redesigned Workflows:
    - Before (Fragmented): Patient → Clinic A → Requests papers → Clinic B → Manually enters in ECE.
    - After (Interoperable): Patient → Clinic A → CURP automatically consulted → Clinic B data retrieved → Available in Clinic A's ECE in <1 second.
3. Training and Organizational Change:
    - Uniform training programs for health professionals in the use of new flows.
    - Cultural shift: from "information custodians" to "collaborators in shared care."
    - Incentives for compliance, public recognition.
4. Shared Governance:
    - Framework agreements between institutions defining:
        - What data to share
        - Permitted purposes (care, public health, research)
        - Security responsibilities
        - Audit and conflict resolution

Success Metrics:

- ≥90% of inter-hospital referrals with shared data.
- Access time to background information during consultation: <5 seconds.
- Clinician satisfaction with new flows: >80%.

Level 4: Legal Interoperability

Objective: To establish a legal framework that provides certainty and legitimacy to data exchange, protecting patients' rights and institutions' obligations.

Components:

1. Aligned Legislative Frameworks:
    - Reform of NOM-024-SSA3-2012 to require FHIR R4.
    - Update of NOM-035-SSA3-2012 for digital privacy.
    - General Law on the Protection of Personal Data (LGPDPPSO) for the public and private sectors.
    - LFPDPPP for the public and private sectors.
2. Interinstitutional Agreements:
    - Confidentiality agreements between IMSS, ISSSTE, IMSS-Bienestar, etc.
    - Integration contracts with private providers and independent clinics.
    - Data Processing Agreements between institutions and the PNI platform.
3. Audit Protocols:
    - Independent annual compliance audit.
    - Unannounced cybersecurity inspections.
    - Public reports of incidents and breaches (within 72 hours).
    - Sanction mechanisms for non-compliance (fines, exclusion from the system).
4. Codified Rights and Obligations:
    - Patient Rights: Access, portability, rectification, deletion (under certain conditions).
    - Institutional Obligations: Confidentiality, security, auditing, breach reporting.
    - PNI Responsibilities: Availability, performance, security.

Success Metrics:

- 100% regulatory compliance in audits.
- <1 security breach per 10 million transactions.
- Conflict resolution in <30 days.[2,8,14]

National and International Reference Standards

The national strategy adopts a set of open, international standards as a mandatory foundation for the entire ecosystem. This adoption is mandatory for new implementations and recommended for legacy systems undergoing transition:

HL7 FHIR R4

Definition:
Fast Healthcare Interoperability Resources (FHIR) is the modern standard for clinical data exchange. It is a specification for:

- Data exchange using REST APIs.
- Representation of resources (Patient, Medication, DiagnosticReport, etc.) in JSON/XML.
- Definition of profiles for specific contexts.

HL7 v2.x

Definition:
HL7 v2.x is the predecessor standard to FHIR, based on messages delimited by special characters. Although technically obsolete, it remains widely used in legacy systems.
Role in National Architecture:

- Transition support for legacy systems from IMSS, IMSS-BIENESTAR, ISSSTE, etc.
- Bidirectional HL7 v2 ↔ FHIR adapters for machine translation.
- Mandatory migration plan: All v2 systems must migrate to FHIR by 2030.

CDA R2

Definition:
CDA is an XML standard for structured clinical documents (clinical notes, discharge summaries, reports).
Applications:

- Clinical summaries on care transitions.
- Specialized consultation notes.
- Surgical procedure reports.

SNOMED CT (Terminology Standard)

Definition:
SNOMED CT is a comprehensive clinical terminology with more than 350,000 concepts for diagnoses, procedures, findings, symptoms.
Adoption in Mexico:

- National License: Agreement with SNOMED International for free access to public health institutions.
- Mexico Extension: Development of national extension with specific terms in the Mexican context (local medications, typical procedures).
- Mandatory Implementation: In diagnoses (Condition), procedures (Procedure), clinical findings (Observation.code) in FHIR.

LOINC (Laboratory and Clinical Observations)

Definition:
LOINC is standard for ~90,000 laboratory test codes, clinical observations, vital signs.
Adoption:

- Mandatory in LIS (Laboratory Information Systems): All laboratory orders and results must be coded in LOINC.
- FHIR Integration: Observation.code field in FHIR DiagnosticReport resources.

ICD-11 (International Classification of Diseases)

Definition:
ICD-11 is the updated statistical classification of diseases, injuries, and health problems (successor to ICD-10).
Adoption Plan in Mexico:

- Phase 1: Pilot implementation in specialized health institutes.
- Phase 2: National deployment in first-level hospitals.
- Phase 3: ICD-10 retirement, full migration to ICD-11.

DICOM (Digital Imaging and Communications in Medicine)

Definition:
DICOM is a standard for storing, sharing and viewing medical images (X-rays, CT scans, MRI).
Adoption:

- De facto standard in radiology and imaging departments.
- Integration with FHIR through DICOMweb (REST APIs for accessing DICOM images).
- Obligatorio en PACS (Picture Archiving and Communication Systems).

Unique Identifiers Strategy

CURP as Universal Primary Identifier:
The fundamental architectural decision is to use CURP (Unique Population Registry Code) as a mandatory unique identifier for all patients in the digital health ecosystem.

Justification:

- Coverage: 95% of the Mexican population.
- Uniqueness: Guaranteed by RENAPO.
- Longevity: It remains with the person for life.
- Transversal Integration: Used by SAT (RFC), Llave MX, IMSS, education, banking.
- Cost: Takes advantage of existing infrastructure.

Representation in FHIR:

```
{
 "resourceType": "Patient",
 "identifier": [
   {
     "system": "http://sistema.salud.gob.mx/curp",
     "value": "AAAA123456HDFNNR09",
     "period": {
       "start": "2025-01-01"
     }
   }
 ]
}
```

Digital Identity and Unique Personal Identification

Strategic Link with National Identity (CURP and MX Key)
The digital identity strategy in health aligns with the Mexican government's broader digital identity agenda, leveraging two existing pillars:

1. Biometric CURP

Starting in October 2025, RENAPO will operate the Biometric CURP, which includes:

- CURP base demographic data alphanumerical (18 characters).
- Biometric data:
    - Fingerprint (10 digitized fingers)
    - Iris (both eyes)
    - High-resolution facial photo

    - QR code that cryptographically encapsulates information.

Advantages for Digital Health:

- Strong multi-factor authentication without the need for passwords.
- Unique identity linking, eliminating the risk of identity theft.
- Reading demographic data directly from the CURP QR code (in doctor's offices, emergencies).

Implementation in Health Ecosystem:

- Biometric readers in health facilities.
- Real-time synchronization with RENAPO for validation.
- Cost sharing: RENAPO provides services, health institutions acquire readers.

2. MX Key (Federal Digital Identity Portal)

The MX Key is the unified federal digital identity portal, which since 2025 integrates services from multiple institutions:

- RENAPO: Base identity (CURP).
- SAT: Tax Identification Number (RFC).
- IMSS: Membership data (NSS).
- Ministry of Finance: Bank account for transfers.
- Others: Driver's license, passport, etc.

For Digital Health:

- MX Key will be the unified authentication portal to access the health portal.
- Using standard OAuth 2.0/OIDC for single sign-on.
- MX Key Tokens are also valid for private telemedicine, digital pharmacy services, etc.

Authentication Flow:

User → Health Portal
↓
"Login with MX Key"
↓
Redirect to MX Key (oauth/authorize)
↓
Enter MX Key credentials (CURP + biometrics)
↓
MX key valid against RENAPO
↓
Token returned to the portal
↓
Authenticated user, access to file

National Master Patient Record (NMPR) and Patient Matching

Patient Matching Functionality
The RMNP implements sophisticated patient matching algorithms to solve the classic duplicate identification problem:
Challenges:

- Name discrepancies ("Jose" vs. "Jose", "María del Carmen" for short).
- Variations in dates (02/03/1975 vs. 1975-03-02).
- Typography: special characters, accents.
- Homonyms: Multiple "Juan García García"s in a country of 130 million.

Matching Algorithms:

1. Exact Matching:
    - CURP + exact name + date of birth → Match confirmed in <100ms.
2. Probabilistic Matching (Feldstein Algorithm + Jaro-Winkler):
    - Comparison of multiple fields (first name, last name1, last name2, date of birth, gender).
    - Confidence score 0-100%.
    - Threshold: >95% triggers manual review.
3. Phonetic Matching (Soundex):
    - For very different names ("Felipe" vs. "Philipe").
4. Temporal Matching:
    - For records of the same patient captured at different times (emergency vs. subsequent consultation).

Deduplication Goal:

- Residual duplicate rate: <1%.
- False positives: <0.1%.

Managing Temporary Identifiers
In emergencies or areas without connectivity, temporary identifiers are assigned and subsequently merged:

- Temporary Identifier: Special prefix (TEMP-AAAA-XXXXX).
- Merger Procedure: When the identity is resolved (CURP entered or biometrically validated), it is merged with the permanent CURP record.
- Timeframe: Automatic merger in <7 days; manual merger after 30 days.
- Audit: Complete merger record for traceability.

Security and Authentication (OAuth 2.0, OpenID Connect, TLS)

Data exchange security is non-negotiable. The architecture implements multiple layers of protection:

Level 1: Encryption in Transit (TLS 1.3+)

Protocolo: HTTPS con TLS 1.3 minimum.
Configuration:

- Suite de cifrado fuerte: TLS_AES_256_GCM_SHA384, TLS_CHACHA20_POLY1305_SHA256.
- Perfect Forward Secrecy (PFS) habilitado.
- Valid X.509 certificates, automatically renewed.
- HSTS (HTTP Strict Transport Security) configurado.

Verification:

- Annual third-party cryptography audit (SSL Labs rating A+).

Level 2: Authentication and Authorization (OAuth 2.0 / OpenID Connect)

For Systems (System-to-System):

- Authentication: mTLS (mutual TLS) certificate.
- Authorization: Specific FHIR Scopes.
    - Example: system/Patient.read (read patient data).
    - Example: system/MedicationRequest.write (create prescription).

Flow:

1. System A presents certificate to PNI
2. PNI validates certificate against trusted list
3. PNI issues JWT tokens with authorized scopes
4. Sistema A incluye token en header Authorization: Bearer <JWT>
5. PNI validates the token signature
6. Authorization according to scopes

For Users (Patient/Provider Logins):

- Protocolo: OAuth 2.0 Authorization Code Flow + OpenID Connect.
- Identity provider: MX Key (federal) or RENAPO (biometric CURP).
- Multi-factor authentication:
    - Factor 1: CURP (knowledge).
    - Factor 2: Biometrics (fingerprint, iris) OR SMS OTP.
    - Factor 3 (optional for sensitive data): Custom security question.

JWT Token (decoded example):

{
  "iss": "https://identidad.pni.gob.mx",
  "sub": "AAAA123456HDFNNR09",
"aud": "my-health-mexico",
  "exp": 1762351200,
  "iat": 1762347600,
  "scopes": ["patient/Patient.read", "patient/Observation.read"],
"name": "Juan Pérez García",
  "email": "juan@example.com",
  "verified_email": true,
  "nonce": "a8b1c2d3e4f5"
}

Level 3: Role-Based Access Control (RBAC) and Consent

Hierarchical RBAC:

- Hospital Admin > Doctor > Nurse > Technician > Patient.
- Each role has specific permissions:
    - Physician: Can view/create/modify diagnoses.
    - Nurse: You can view observations, update vital signs.
    - Patient: You can see your own file.

Real-Time Consent Validation:

Clinic B system requests: GET /Observation?patient={CURP}
↓
PNI consultation RMNP: Does Clinic B System have patient consent?
↓
Consent exists and is in force: YES
↓
PNI routes to IMSS, ISSSTE, obtains data
↓
Filter data according to the scope of consent
↓
Returns only allowed observations

Level 4: Audit and Anomaly Detection

Immutable Audit:

- Centralized log of EACH access to clinical data:
    - User/System that accessed
    - Specific resource
    - Time/date
    - IP origen
    - Result (success/failure, data returned)
- Storage: Blockchain o base de datos append-only.
- Retention: 7 years minimum.

Anomaly Detection (Machine Learning):

- Unusual access (e.g., cardiology physician accessing 1,000 patients in 5 minutes).
- Access to family/friends' data (potential privacy violation).
- Inconsistent geolocation (login from 2 cities in 10 minutes).
- Automatic alerts if suspicious patterns are detected.

V. Implementation and Adoption

Phased Implementation Roadmap

The implementation of the national digital health strategy will be carried out through a progressive and adaptive roadmap, designed to mitigate risks, deliver early clinical value, generate buy-in, and ensure long-term sustainability.

This plan is structured in three macroscopic phases (2025-2030) ranging from the construction of the foundations to the consolidation and maturity of the ecosystem, with specific milestones, exit criteria, and budget estimates.

Phase I: Foundations and Pilots

Phase Vision:
Establish the essential technical, regulatory, operational, and governance foundations for interoperability through a functional PNI MVP, carefully selected institutional pilots, and updated regulatory frameworks. The emphasis is on demonstrating viability, building political trust, and capturing lessons learned early.

Objective and Justification

- Functional PNI MVP: Demonstrating that heterogeneous systems can exchange clinical data securely and meaningfully.
- Pilot in key institutions: Validate workflows with IMSS, ISSSTE, IMSS-Bienestar, etc., in specific geographic areas.
- Published Standards: FHIR-MX v0.9 available for third-party integration development.
- Updated legal framework: Modernized regulations with digital transformation and interoperability requirements.

Key Milestones and Deliverables

Milestone 1.1: Launch of the PNI MVP

- National Interoperability Platform (PNI) - Minimum Viable Product:
    - Deployment on AWS/Azure/national cloud infrastructure.
    - API Gateway FHIR R4 con endpoints para recursos esenciales: Patient, Encounter, Observation, DiagnosticReport, MedicationRequest.
    - National Master Patient Registry (NMPR) with:
        - Master Patient Index based on CURP.
        - Synchronization with RENAPO for identity.

        - Automatic deduplication (<1% duplicates).
    - Immutable Audit System: Centralized log of all transactions (who accessed what data, when).
    - Endpoint Directory: Record of where each institution's FHIR services are hosted.
    - Initial availability: 99.5% SLA.
- Technical Capacity:
    - 10,000 req/min is a pico.
    - Latency <2 seconds p95.
    - Near-real-time data synchronization (<1 second for critical changes).
- Base Security:
    - TLS 1.3+, mTLS for system-to-system.
    - OAuth 2.0 with initial integration to MX Key.
    - AES-256 encryption for data at rest.
    - NIST CSF 2.0 Tier 1-2 Compliance.

Hito 1.2 : FHIR-MX v0.9 Beta

- FHIR-Mexico (FHIR-MX) Implementation Guide Version 0.9:
    - Perfiles de recursos críticos: Patient-MX, Encounter-MX, Observation-MX-Lab, Condition-MX, Medication-MX, MedicationRequest-MX, DiagnosticReport-MX.
    - Value Sets for SNOMED CT, LOINC, RxNorm (initial mappings).
    - Conformance Profile specifying implementation requirements.
    - 50+ concrete examples of FHIR instances for Mexican cases.
    - Documentation of national extensions (Professional Certificate, affiliation institution).
- FHIR-MX Sandbox:
    - Production mirror environment for developers.
    - 50,000 fictitious patients with realistic clinical data.
    - Validador FHIR-MX online (sube JSON/XML, obtén feedback instantáneo).
    - Postman Collection preloaded with 30+ use cases.
    - Visual API Tester without code.
    - Free access with no limit on requests (sandbox goal: 1,000,000 requests/month).
- Documentation:
    - Step-by-step tutorial for implementers.
    - Troubleshooting guide with common cases.
    - Video guides (3-5 minutes each).

Milestone 1.3: Health Portal Beta

- Beta Version of the Citizen Portal:
  - Authentication: CURP + Biometrics (fingerprint/iris) OR SMS OTP.
  - Views of the File:
    - Health Summary: Allergies, Blood Type, Chronic Conditions
    - Query History: last 12 months, institutions visited.
    - Laboratory Results: last 60 days, by institution.
    - Active Medications: consolidated from all institutions.
    - Vaccinations: complete record from childhood.
  - Consent Management: Visual dashboard of which institutions have access to which data.
  - Portability: Download file in FHIR JSON, PDF, CSV.
  - Notifications: Alerts for new results, pending medications.
  - Availability: Web + iOS/Android Apps.
  - Registered user target: 1 million by the end of 2025.

Milestone 1.4: Updated Legal Framework

- Draft NOM-024-SSA3-2012 Updated:
  - It incorporates FHIR R4 as standard (in addition to maintaining transitional support for HL7 v2).
  - Defines technical, semantic, and organizational interoperability requirements.
  - Specifies audit and compliance.
  - Publication in DOF for public consultation (30 days).
- Electronic Prescription Guidelines:
  - Operational framework for national electronic prescriptions.
  - Advanced electronic signature mechanisms.
  - Published by COFEPRIS in coordination with SSA.

Milestone 1.5: Pilots in 5 Key Institutions

- Selection of Pilot Sites in a First Level Hospital, Private Hospital, Pharmacy and Office attached to a Pharmacy.
- Clinical Pilot:
  - Laboratory Integration: Laboratory Orders and Results.
  - Imaging Integration: Structured radiology reports, access to DICOM images.
  - Interhospital Referral: Sending a clinical summary using FHIR.
  - Metrics:
    - 100 referrals between hospitals/month.
    - Access time to previous data in emergencies: <5 minutes.

        - Clinician satisfaction: >70%.
- Rural Pilot:
    - Satellite connectivity (offline-first, asynchronous synchronization).
    - Patient registry with biometric CURP.
    - Telemedicine for specialized consultation with a referral hospital.
    - Metrics:
        - 80%+ access to historical records.
        - Teleconsultations facilitated: 50+/month.

Milestone 1.6: ECE Systems Certification

- Basic Level Certification Program:
    - ECEs of pilot institutions pass audit:
        - FHIR R4 compliance (automatic validation).
        - Security: TLS, authentication, encryption.
        - Audit: immutable logs.
    - Certification: Official seal "FHIR-MX Compliant".

Milestone 1.7: Evaluation and Adjustments

- Phase I Evaluation:
    - Did MVP PNI achieve 99.5% uptime? ✓
    - 95%+ of FHIR-MX compliant pilot messages? ✓
    - Lessons learned captured? 50+ page document.
    - Validated ROI projections?
- Continuity Decision:
    - If criteria are met: Advance to Phase II with increased budget.
    - If not: 6-month stabilization phase before expanding.

Phase II: National Scaling and Value Cases (2027 – 2029)

Phase Vision
With the foundation in place, this phase focuses on national expansion of the PNI, demonstrating clinical and economic impact, and implementing high-value workflows (e-prescribing, integrated telemedicine, seamless inter-institutional referrals). The goal is for 80%+ of the public sector to be connected and 50%+ of prescriptions to be digital.

Key Milestones and Deliverables

Milestone 2.1: Expansion to Federal Entities

- Phase 2a (Q1-Q2 2027): Group 1 – High Capacity Entities:
    - Mexico City, Jalisco, Nuevo Leon, Guanajuato, Veracruz.
    - Existing technical capacity, committed political leadership.

    - Mandatory connection of general hospitals and laboratories.
    - Target: 100% of 2nd/3rd level establishments connected.
- Phase 2b: Group 2 – Medium-sized Entities:
    - Coahuila, Sonora, Chihuahua, Baja California, Yucatan, Oaxaca.
    - Intensive technical support from DGMoSS (travel, on-site training).
    - Goal: 80% of establishments connected.
- Phase 2c: Group 3 – Lower Capacity Entities:
    - Campeche, Nayarit, Tlaxcala, Colima, Durango, etc.
    - Alternative connectivity models (satellite, mobile 4G).
    - Goal: 60% of establishments connected.
- Infrastructure by Entity:
    - Replicated PNI state node.
    - Local storage of sensitive data (compliance with LGPDPPSO).
    - Synchronization with national PNI every 30 minutes.

Milestone 2.2: National Electronic Prescription Phase 1

- Electronic Prescription Launch (Basic Table):
    - Catalog of 300+ medications from the SS basic list.
    - Flow:
        1. Physician issues MedicationRequest in ECE.
        2. System generates FHIR + cryptographic QR recipe.
        3. Prescription sent to pharmacy via PNI.
        4. Pharmacist validates digital signature.
        5. Dispenses medication.
        6. Confirmation recorded in the patient's ECE.
    - Security: Advanced electronic signature, end-to-end encryption.
    - Initial participants: IMSS (50,000+ pharmacies), ISSSTE (3,000+ pharmacies), participating private pharmacies (1,000+).
    - Goal: 50%+ of digital outpatient prescriptions.

Milestone 2.3: Integrated Telemedicine

- Integration of Remote Consultations in ECE:
    - Telemedicine platforms integrate with PNI.
    - Remote consultation generates Encounter FHIR automatically registered in the patient's ECE.
    - Telemedicine prescriptions flow to the pharmacy digitally.
    - Telemedicine diagnostics available to the next provider.
    - Compliance: Updated NOM-024 requires telemedicine to generate interoperable records.
- National Deployment:

        - IMSS: 10,000 teleconsultations/day (2027).
        - ISSSTE: 3,000 teleconsultations/day.
        - Private sector: 5,000 teleconsultations/day.
        - Goal: 100,000 teleconsultations/month registered in PNI.

Milestone 2.4: Sector Security Operations Center (SOC)

- Establishing 24/7 SOC:
    - Staff: 25 healthcare cybersecurity specialists.
    - Functions:
        - Continuous monitoring of PNI and connected systems.
        - Anomaly detection (ML-powered).
        - Incident response (<1 hour for critical alerts).
        - Audit log analysis.
        - Regulatory compliance (NIST CSF 2.0 Tier 2-3).
    - Location: PNI main data center.
    - Investment: 180 MXN million/year.

Milestone 2.5: ISO 27001 Certification

- PNI obtains ISO/IEC 27001:2022 certification:
    - Annual external audit.
    - Continuous review of security controls.
    - Public incidents reported within 72 hours.
    - Goal: Zero major breaches (>10,000 records exposed).

Milestone 2.6: Expansion of Laboratories and Imaging

- National Integration of Laboratories:
    - 3,500+ private and public laboratories connected.
    - FHIR Orders: Physician orders, PNI routes to lab.
    - FHIR Results with LOINC: Standard Test Codes.
    - Validation of normal ranges by age/sex.
    - Goal: 95%+ interoperable laboratories.
    - Benefit: Elimination of duplicate tests (~30%).
- National Imaging Integration:
    - 800+ interconnected PACS (radiology, CT, MRI) devices.
    - FHIR DiagnosticReport reports + DICOM images via DICOMweb.
    - Remote access to images from any authorized institution.
    - Integrated AI Radiology: AI assists in reading X-rays.
    - Goal: 85%+ of images digitally available in <30 minutes.

Phase III: Consolidation, Analytics and Maturity (2030 – 2033)

Phase Vision:

The final phase seeks to consolidate the ecosystem nationwide, ethically leverage data for population surveillance and research, achieve operational maturity and security, and demonstrate a demonstrable impact on public health. Goal: 130 million citizens with interoperable medical records, 95%+ of digital prescriptions, and a system operating with maximum efficiency and security.

Key Milestones and Deliverables

Milestone 3.1: Full Coverage and Private Adherence

- Public Sector Coverage: 100%
    - All IMSS, ISSSTE, IMSS-Bienestar, and SSA establishments are connected.
    - Small rural hospitals with offline-first connectivity.
    - 130 million citizens with interoperable records.
- Voluntary Adherence Private Sector:
    - Private hospitals (200+): Incentivized connection.
    - Specialty Clinics (500+): Facilitated Integration.
    - Offices attached to pharmacies (10,000+): Simplified access.
    - Target: 30%+ of the private sector connected.

Milestone 3.2: Federated Data Lake

- Federated Architecture for Analytics:
    - Clinical data remain at the originating institutions.
    - Analytic queries are distributed to local nodes.
    - Aggregated results in PNI without centralizing sensitive data.
    - Compliance: LGPDPPSO, Data Protection Law.
- Analytical Use Cases:
    - Epidemiological Surveillance: COVID-19, dengue, tuberculosis detected in real time.
    - Medication Management: Identify antibiotic overprescriptions and interactions.
    - Health Equity: Compare mortality rates across states, identify factors.
    - Epidemiological Research: Cohort studies with 10+ million patients.
- Governance Framework:
    - "Public Interest Licensing": Researchers and public health authorities can access anonymized data.
    - Collective Consent: Communities authorize the use of data for public health.
    - Ethics Committee: Review of data access requests.

Milestone 3.3: Electronic Prescription Phase 2 (Controlled Medications)

- Extension to Controlled Drugs:
    - Integration with COFEPRIS for consumption registration.
    - Enhanced security mechanisms: Patient biometrics, online verification.
    - Prevention of duplicate prescriptions (search in national PNI).
    - Drug tracking from pharmacist → pharmacy → patient.
    - Compliance: United Nations Convention on Psychotropic Substances.

Milestone 3.4: Cybersecurity Maturity (NIST CSF 2.0 Tier 3)

- NIST CSF 2.0 Maturity Levels:
    - Tier 1 (Reactive): Post-incident response.
    - Tier 2 (Preventive): Policies defined.
    - Tier 3 (Proactive): Integrated management, continuous metrics.
    - Tier 4 (Adaptive): Automatic response, continuous learning.
- Actions to Reach Tier 3:
    - Annual risk assessments for each institution.
    - Penetration testing by independent third parties (red team).
    - Malware analysis and attack patterns.
    - Minor incident response automation.
    - Monthly internal audits, quarterly external audits.
- Success Indicators:
    - <1 security breach per 10 million transactions.
    - Average remediation time: <24 hours.
    - 100% of staff with annual cybersecurity certification.

Milestone 3.5: Innovation and Integrated AI/ML

- Clinical Artificial Intelligence:
    - AI-Assisted Diagnosis: Models trained with FHIR data from millions of patients.
        - Radiology: AI detects lesions with 99%+ accuracy.
        - Pathology: IA analyzes histological samples.
        - EHR NLP: Automatic extraction of diagnoses from unstructured clinical notes.
    - Risk Prediction: Algorithms identify patients at high risk of decompensation (diabetes, hypertension).
    - Medication Management: Personalized dosage recommendations based on weight, age, and kidney failure.
- Privacy-Preserving (Federated Learning):
    - Models trained on local data without centralizing sensitive information.
    - Only model gradients are exchanged between nodes.

- Compliance: LGPDPPSO, differential privacy.

Capacity Building and Workforce Development

Technology alone does not generate transformation. A massive, sustained, and differentiated skills development program for healthcare professionals, IT staff, administrators, and the general public is essential. The WHO estimates that changing organizational culture in healthcare requires an investment equivalent to 20-30% of the technology budget.

Digital Literacy for Clinical Personnel: National Digital Literacy Program in Health (PNADIS)

A structured, accredited program will be implemented with differentiated paths by role and specialization:

Level 1: Basic Literacy (40 hours)
Audience: General practitioners, nurses, hospital administrative staff.
Goals:

- Efficiently use the ECE: navigation, data entry, information search.
- Understanding digital workflows and their impact on care.
- Basic principles of information security and data protection.
- Managing the health portal from a professional perspective.

Contents:

- Module 1 (8h): Introduction to ECE and FHIR (non-technical concepts).
- Module 2 (8h): Workflows: patient admission, test order, results recording.
- Module 3 (8h): Security and confidentiality: data access, auditing, consequences of violations.
- Module 4 (8h): Patient consent, portability, digital rights.
- Module 5 (8h): Basic troubleshooting, support contacts.

Level 2: Intermediate Literacy (80 hours)

Audience: Medical specialists, quality coordinators, clinical service leaders, clinical informatics staff.
Goals:

- Understand interoperability principles and FHIR/HL7 standards in a clinical context.
- Use interoperable clinical data for decision-making (e.g., compare results from different laboratories).
- Participate in the design of digitally optimized clinical processes.
- Interpretation of quality metrics and KPIs.

Contents:

- Module 1 (12h): Clinical standards: FHIR, SNOMED CT, LOINC, ICD-11 (non-technician).
- Module 2 (12h): Organizational interoperability: reference/counter-reference flows, quality agreements.
- Module 3 (16h): Analytics and BI: how to access aggregated data, create reports.
- Module 4 (16h): Process improvement: redesigning flows to take advantage of digital data.
- Module 5 (12h): Advanced cybersecurity: encryption, auditing, incident management.
- Module 6 (12h): Ethics in health data: consent, privacy, equity.

Level 3: Advanced Literacy (120 hours)

Audience: Clinical researchers, epidemiologists, medical informatics specialists, healthcare IT managers, decision makers.
Goals:

- Designing studies that leverage interoperable FHIR data.
- Advanced analytics: machine learning, big data, population analysis.
- Data governance: collective consent, ethical secondary use.
- Innovation: AI, telemedicine, precision.

Contents:

- Module 1 (15h): Health data mining: extraction, cleaning, validation.
- Module 2 (20h): Machine Learning for clinical prediction: risks of readmission, mortality.
- Module 3 (20h): Causal analysis: identification of determining factors in health.
- Module 4 (15h): Privacy-preserving: federated learning, differential privacy.
- Module 5 (15h): Ethics in data research: consent, equity, bias.
- Module 6 (20h): Case studies: COVID-19 surveillance, tuberculosis, equity.
- Module 7 (15h): Project presentation and defense.

Monitoring, Evaluation and KPIs
A robust Monitoring and Evaluation (M&E) framework is essential to measure progress, demonstrate investment value, facilitate continuous improvement, and ensure accountability to citizens. This framework is based on a clear Theory of Change and aligns with methodologies from the WHO, the World Bank, and PAHO.

Conceptual Framework: Logic of Change

INPUTS (Investment)
↓
PROCESSES (Activities)
↓
PRODUCTS (Deliverables)
↓
RESULTS (Changes)
↓
IMPACT (Effects on Population Health)

Key Performance Indicators (KPIs)

A publicly accessible National Health Interoperability Dashboard will be implemented inhttps://tablero.pni.gob.mx, updated daily, with segmentation by federal entity, level of care, and demographic variables to measure equity.

Coverage Indicators (Infrastructure)

KPI	Code	Definition	Meta 2026	Meta 2028	Meta 2030
% Establishments connected to PNI	COB-001	(Establishments with active FHIR API / Total establishments) x 100	20%	80%	95%
% Physicians using interoperable EHR	COB-002	(Doctors with active session in the last 30 days / Total doctors) x 100	30%	75%	95%

% Population registered in RMNP	COB-003	(Citizens with CURP in RMNP / Total population) x 100	40%	75%	98%
% Laboratories exchanging data	COB-004	(Laboratories sending FHIR results / Total laboratories) x 100	25%	80%	90%
PNI Availability (Uptime)	COB-005	(Available hours / Total hours) x 100	99.5%	99.8%	99.95%

Process

Indicators (Clinical Adoption)

KPI	Code	Definition	Meta 2026	Meta 2028	Meta 2030
% Consultations with interoperable file available	ADO-001	(Consultations where the doctor accessed previous data / Total consultations) x 100	25%	75%	90%
% Digital prescriptions	ADO-002	(FHIR Prescriptions / Total Prescriptions) x 100	10%	60%	95%
% Teleconsultations registered in PNI	ADO-003	(Telemedicine encounters with FHIR registration / Total teleconsultations) x 100	20%	80%	95%

% References with digital clinical summary	ADO-004	(References with FHIR Composition sent / Total references) x 100	15%	70%	85%
Average time to access medical history in the emergency room	ADO-005	Time from login to viewing previous data (minutes)	<10 min	<5 min	<3 min

Outcome Indicators (Clinical Impact)

KPI	Code	Definition	Meta 2026	Meta 2028	Meta 2030
Reduction of duplicate studies	RES-001	(1 - Duplicate Tests 2025 / Duplicate Tests 2025) x 100	15%	35%	50%
Reduction of medication errors	RES-002	(1 - Errors 2025 / Errors 2025) x 100	10%	25%	40%
Reduced diagnosis time	RES-003	Average number of days from initial symptom to confirmed diagnosis	-5 days	-15 days	-25 days
Satisfaction of health professionals	RES-004	% who report "satisfied" or "very satisfied" with ECE (annual survey)	50%	75%	85%

Patient satisfaction (portal)	RES-005	% active users of the "Mi Salud México" portal in the last 30 days	5%	30%	50%

Impact Indicators (Population Health)

KPI	Code	Definition	Meta 2026	Meta 2028	Meta 2030
Reduction of hospital mortality	IMP-001	Hospital mortality rate/1,000 discharges (reduction compared to 2025)	-5%	-15%	-25%
Reduction of cross-infections	IMP-002	Nosocomial infection rate/1,000 discharges (reduction)	-10%	-30%	-40%
Improved vaccination coverage	IMP-003	% of population with complete vaccination schedule	+3%	+8%	+12%
Equity in access	IMP-004	Gap in % of digital files between entities with the highest and lowest coverage	-20%	-50%	-70%

Security and Privacy Indicators

KPI	Code	Definition	Meta 2026	Meta 2028	Meta 2030

Cybersecurity incidents	SEG-001	# security breaches with ≥1,000 exposed records/year	<2	<1	0
Average remediation time	SEG-002	Hours from vulnerability detection to patch applied	<72h	<48h	<24h
Audit regulatory compliance	SEG-003	% of institutions that pass annual data protection audit	70%	90%	98%
Incidents of violation of consent	SEG-004	# unauthorized access to clinical data detected/year	<100	<20	<5

Digital Maturity Model in Health

In addition to the KPIs, a Maturity Model will be used to assess the evolution of institutional capabilities:

Dimensions of Maturity

Dimension	Level 1: Initial	Level 2: Defined	Level 3: Managed	Level 4: Optimized
Governance	To this end	Documented policies	Periodic review	Automatic continuous improvement
FHIR technology	Not implemented	Pilot APIs	Production, >80% compliance	Production, >99% compliance

Data	Silos	Manual integration	Automatic, validated	Federated, AI-optimized
Security	Basic (Tier 1)	Proactive (Tier 2)	Integrated (Tier 3)	Adaptive (Tier 4)
Talent	Ad hoc training	Initial Certification	Annual recertification	Advanced programs

VI. Case Studies and Applications

National and International Case Studies

The digital transformation of the health sector is a complex global challenge that combines technical, organizational, political, and cultural challenges. Analyzing international experiences offers valuable lessons about success factors, common pitfalls, and critical contexts, allowing Mexico to adapt best practices to its unique reality—combining the ambition of transformation with the pragmatics of implementation in a fragmented federal system.
This section analyzes four international models of utmost relevance to Mexico, drawing key lessons that inform national strategy.

Estonia:

Context and Vision
Estonia is a world leader in the digital transformation of the public sector and digital health. Since its independence in 1991, it faced the urgent need to build modern institutions without legacy infrastructure. This constraint became an opportunity: Estonia decided to build a digital ecosystem from scratch focused on security, decentralization, and citizen trust.

Central Pillar: X-Road (Secure and Decentralized Data Exchange)
X-Road is a national data exchange infrastructure connecting >800 public and private organizations (including hospitals, pharmacies, insurers, government).

Technical Characteristics:

- Decentralized Architecture: Each organization maintains its own data; X-Road is merely the communication bus.
- Strong Security: AES-256 encryption, digital signatures, mandatory multi-factor authentication.
- Immutable Audit: All access is logged; citizens can see who accessed their data (radical transparency).
- REST/SOAP APIs: Technical interoperability through open standards.

Implementation in Health:

- 99% of health data digitized since 2008.
- Citizens can access their complete medical records 24/7 through the e-Health portal.
- Electronic prescriptions have been mandatory since 2010; pharmacies can automatically check them.
- Labs, imaging, specialists—all exchange data through X-Road.

Sustained Political Leadership:

- One of the critical success factors was bipartisan political commitment that transcends election cycles.
- The government treats digital transformation as critical national infrastructure, analogous to roads or electricity.
- Privacy and security laws passed under governments of different parties, maintaining continuity.

Citizen Confidence:

- Surveys show 80%+ public confidence in e-Health.
- Citizens can exercise access auditing: automatic notification when someone accesses their data.
- Cases of unauthorized access result in criminal prosecution.

Clinical and Operational Results

- Preventable mortality: 15-20% reduction attributed to faster diagnoses.
- Medication errors: 40% reduction due to interaction detection.
- Citizen satisfaction: 85%+ portal users.
- Efficiency: Referral process reduced from 2-3 weeks to 1-2 days.

Key Lessons for Mexico

Lesson	**Applicability to Mexico**	**Necessary Adaptation**
Sustained political leadership	Very high	Requires multi-party commitment at the federal level
Decentralized architecture	High	Aligns with Mexican federalism
Radical transparency (citizen audit)	Medium-High	Requires cultural change and protections against retaliation
Adoption of open standards	High	FHIR-MX aligned with X-Road principles

Safety as a central priority	Very high	NIST CSF 2.0, ISO 27001 mandatory

Denmark: Interoperability in Decentralized System (MedCom)

Context
Denmark, with ~5.8 million inhabitants and a highly decentralized health system (regions and municipalities with self-government), has achieved high interoperability despite structural fragmentation. Key: MedCom, the national health communication network established in 1994.

MedCom: Collaborative Governance at Scale
Organization:

- Public-private consortium of hospitals, municipalities, pharmacies, and insurance companies.
- Mixed financing: 40% public funds, 40% membership fees, 20% complementary services.
- Governance: Board of directors with representatives from all sectors.

Pragmatic Standardization:

- Rather than imposing a single standard from above, MedCom agreed on standards for use cases of greatest clinical value, starting with:
    - Clinical messaging (referrals, consultations)
    - Laboratory orders
    - Laboratory results
    - Medical prescriptions

Current Capacity (2024):

- 80+ million clinical messages processed annually by MedCom.
- 150+ standardized message types for clinical workflows.
- 500+ connected organizations.
- Uptime: 99.95% (critical reliability for emergencies).

Messaging Model: EDIFACT, HL7 v2, Migration to FHIR
Evolution:

- 1994-2010: EDIFACT (structured message format).
- 2010-2025: HL7 v2.x (de facto clinical standard in Denmark).
- 2025+: Transition to FHIR (more flexible, compatible with global ecosystem).

Advantage of the Gradual Approach:

- Denmark did not force disruptive changes; it allowed for the temporary coexistence of standards.
- Organizations migrate to FHIR when they are ready, without artificial deadline pressure.

Sustainable Financing

- Annual fee per organization: 5,000-50,000 EUR depending on size/type.
- Additional services (audit, analysis, training) generate income.
- Public funds ensure accessibility for small rural hospitals.
- Model is self-sustaining after initial investment.

Results

- Reduction of administrative errors: 30-40%.
- Reduced reference time: from weeks to 24-48 hours.
- Clinician Satisfaction: 75%+ find value in interoperability.
- Surveillance Support: During COVID-19, MedCom facilitated rapid outbreak tracking.

Lessons for Mexico

Lesson	Applicability	Adaptation
Collaborative (non-authoritarian) governance	Very high	DGMOSS model as facilitator, not dictator
Mixed public-private financing	High	70% public, 30% multilateral/private for Mexico
Pragmatic standardization (priority use cases)	Very high	Start with lab, recipes, references
Temporary coexistence of standards	High	HL7 v2 + FHIR simultaneously during transition
Gradual scalability	Very high	Phases I-III reflect this approach

United Kingdom: Lessons from Failure (NPfIT) and Subsequent Success (NHS Digital)

Context: The NPfIT Catastrophic Project (2002-2011)
The National Programme for Information Technology (NPfIT) is one of the most ambitious—and failed—e-health initiatives in history.

Features:

- Initial budgeted cost: £6.8 billion (2002).
- Final cost: ~£11-12 billion (after partial cancellation).
- Total time: 9 years for cancellation.
- Objective: A single electronic health record system for 50 million citizens.

Reasons for Failure:

1. Big Bang: Attempting to simultaneously replace all legacy systems in the NHS (200+ hospitals) with a single monolith.
2. Complex Specifications: Bloated technical requirements; EHR was supposed to be "all things to all people," which made the software inflexible.
3. Lack of Clinical Participation: Physicians were not consulted in the design; the software did not reflect real-world workflows.
4. Single Technology Dependency: Single contract with Cerner; no upgrade options if the software fails.
5. Clinical Rejection: Doctors rejected the system for being slow, unintuitive, and not improving care.

Result:

- Cancelled in 2011 with minimal value delivered.
- NHS had to revert to legacy systems.
- Huge opportunity cost: resources that could have been allocated to clinical care.

Subsequent Success: NHS Digital (2013-2025)

From the ashes of NPfIT, NHS Digital emerged with a radically different strategy:
Fundamental Changes:

1. Modular (Non-Monolithic) Approach: Multiple systems can coexist; compatibility via APIs.
2. Open APIs, FHIR Standards: Instead of a central EHR, NHS exposes FHIR APIs that third parties can integrate.
3. Active Clinical Participation: Doctors and nurses design specifications; they own the change.
4. Plural Suppliers: Multiple vendors compete; NHS maintains technological independence.

5. Citizens as a Priority: The NHS App (citizen portal) is the entry point; it integrates appointments, prescriptions, results, and recommendations.

Implementing NHS Digital:

- NHS App (Citizens Portal):
    - Released 2019; 15+ million downloads (30%+ population).
    - Features: access to records, appointments, repeatable prescriptions, service requests.
    - Integration with multiple hospitals/clinics without a monolithic core system.
- FHIR API Standards:
    - NHS Define FHIR Implementation Guide (IG).
    - Hospitals implement APIs in compliance with IG.
    - Third parties develop apps that consume APIs.
- Programa "NHS API Ecosystem":
    - Sandbox for developers.
    - Extensive documentation.
    - 100 third-party apps built on NHS APIs.

Results

- Citizen adoption: 30%+ of the population uses the NHS App regularly.
- Efficiency: Paper reduction, automation of administrative processes.
- Flexibility: Hospitals can update systems without central synchronization.
- Innovation: Startups develop health applications leveraging open APIs.

Critical Lessons for Mexico

Lesson	**Applicability**	**Adaptation**
Avoiding the Big Bang: Modular, Federated, Gradual	Criticism	Roadmap Phases I-III reflects this
Clinical Participation from the Beginning: Co-design	Criticism	FHIR-MX Design Clinicians, Pilots
Open APIs, Multiple Vendors: Independence	Very high	PNI as public infrastructure; private systems compete

Citizens as a Center: Accessible Portal	Very high	"My Health Mexico" priority Phase I
Transparency about Failures: Learning from NPfIT	High	Clear communication of lessons learned

Brazil: Large-Scale Digital Transformation in a Latin American Context (RNDS)

Context
Brazil, with 130 million+ inhabitants, a federal health system (SUS), and fragmentation comparable to Mexico, faced similar challenges: data silos, lack of interoperability, and inequity in access. In 2020, Brazil launched the National Health Data Network (RNDS).
RNDS: Mandatory National Architecture in FHIR

Critical Strategic Decision:

- FHIR was adopted as a mandatory standard from the beginning (no gradual transition).
- All health institutions (public, private, supplementary) must be connected.
- Governance: Ministry of Health + ANVISA + technical operator (state-owned company).

Current Capacity (2024):

- 30,000+ connected health units (hospitals, clinics, laboratories, pharmacies).
- 300+ million events/year processed.
- Coverage: 80%+ of the Brazilian population.

Catalyst: COVID-19
The pandemic dramatically accelerated adoption:

- Real-time surveillance: RNDS facilitated tracking of COVID-19 cases, variants, and impact on hospitalizations.
- National Coordination: Ministries, states, and municipalities shared data in a standardized manner.
- Research: RNDS data used for epidemiological studies on the effectiveness of vaccines and treatments.

Result: RNDS proved its viability under extreme pressure; it is now a cornerstone of Brazilian public health.
Challenges Overcome

1. Legacy Systems Resilience: Institutions with older ECEs had to adapt or replace them. Solution: 2-3 year transition period, national technical support.
2. Technical Capacity Disparities: Large private hospitals vs. rural clinics. Solution: RNDS provides clear specifications; third parties develop customized solutions.

3. Poor Data Quality: A lot of noise in historical data. Solution: Automatic validation at the shipping point; rejection of non-compliant data.
4. Privacy and Consent: Legal Challenges Regarding Data Sharing. Solution: Privacy Framework in Data Protection Law (Lei Geral de Proteção de Dados - LGPD), Explicit Consent.

Observed Results and Benefits

- Epidemiological Surveillance: Real-time outbreak detection (meningitis, dengue, COVID-19).
- Medication Management: Identifying medication shortages in real time during crises.
- Research: Population studies on treatment effectiveness.
- Equity: Data by region/municipality allow for the identification of health inequalities.

Lessons for Mexico

Lesson	Applicability	Adaptation
FHIR Required from Start: Consistency	Very high	FHIR-MX v1.0 required in Phase II
Realistic Transition Period: 2-3 years	Very high	Similar deadline in roadmap
Central Technical Support: Training, tools	Very high	DGMoSS provides sandbox, documentation
Automatic Validation: Data QA	Very high	FHIR Validator in PNI rejects non-compliant data
Crisis Catalyst: Accelerates adoption	Media	COVID-19 surveillance in Brazil; applicable to national epidemiological surveillance

Legal Privacy Framework: Brazilian LGPD	Very high	Mexico has LFPDPPP/LGPDPPSO; alignment necessary

Conclusion

The **Digital Transformation and Interoperability in Health**It is not a technological project, but a national commitment. It represents the commitment to building a health system that listens, learns, and adapts in real time to the needs of each person. Today, **Mexico**has the historic opportunity to overcome the fragmentation that has limited its potential and make a leap towards a**connected, equitable, and trustworthy ecosystem**, where information flows securely, innovation accelerates, and the patient regains the center of care.

This change requires leadership and co-responsibility. Public institutions must assume the leading role and guarantee equity, ensuring that no region or group is left behind. The private sector and technology developers are called upon to innovate purposefully, adopting open standards and contributing to national interoperability. Academia and society, for their part, are custodians of the ethics, evidence, and transparency that sustain public trust. Every actor, from legislators to doctors, from engineers to citizens, has a role to play in this collective process.

The objective is clear, andThe regulatory framework, technical standards and architecture provide a solid foundation for moving forward safely. However, success will not depend on systems, but on the willingness to collaborate across sectors and levels of government. **Digitally transforming healthcare means transforming the way we work together, share knowledge, and put data to work for the common good.**

We call on health system leaders to move from planning to implementation. To invest not only in infrastructure, but also in talent, trust, and governance. To recognize that interoperability is not an end, but a means to guarantee a human right: the right to continuous, safe, and dignified care.

The future of Mexican healthcare depends on the decisions we make today. Let this guide be more than a document: let it be the starting point for a national alliance for inclusive, sustainable, and people-centered digital health. The time is now. Transforming together is the only way to ensure the well-being of all.

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