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Digital Transformation Readiness in Hospital Pharmacy Operations

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ABSTRACT— Hospital pharmacies occupy a critical juncture where decisions about care, medication safety, and supply chain integrity intersect. With rapid digital innovation in health systems towards e-prescribing, bar-coded medication administration, clinical decision support, automated dispensing cabinets, and analytics, the true key factor for success is not digital adoption but organizational readiness for transformation. In this manuscript, we propose a holistic and evidence-based framework to evaluate "digital transformation readiness" (DTR) in hospital pharmacy practice. Through a synthesis of theoretical perspectives related to people-process-technology alignment, socio-technical system theory, change management, and capability maturity, we develop the Pharmacy Digital Transformation Readiness Index (Pharm-DTRI), which encompasses eight domains: Strategy & Governance; Culture & Change Management; Workforce & Skills; Process Standardization; Data & Interoperability; Technology & Infrastructure; Safety & Cybersecurity; and Value Realization & Continuous Improvement.

We outline a mixed-methods methodology using a validated Likert-scale survey, semi-structured interviews, system log analytics, and document review. The study protocol covers sampling across multiple hospital profiles, instrument development (content validation, pilot testing, reliability checks), and an analytic plan that includes exploratory and confirmatory factor analysis, latent class clustering for maturity tiers, and structural equation modeling to examine how readiness predicts key pharmacy outcomes (medication error rates, turnaround time, inventory stockouts, and clinical intervention rates). We also present illustrative (hypothetical) findings showing how targeted interventions—such as standardizing order sets and upskilling technicians in data literacy—can shift readiness by one maturity level within a year, with downstream improvements in safety and efficiency metrics.

By moving beyond ad hoc technology rollouts to an evidence-based readiness program, hospital pharmacies can de-risk investments, stage change in pragmatic waves, and build a durable capability for continuous digital improvement. The proposed Pharm-DTRI and protocol provide a practical blueprint for benchmarking, prioritizing roadmaps, and monitoring benefits realization.

Keywords— hospital pharmacy, digital transformation, readiness assessment, capability maturity, interoperability, medication safety, automation, analytics

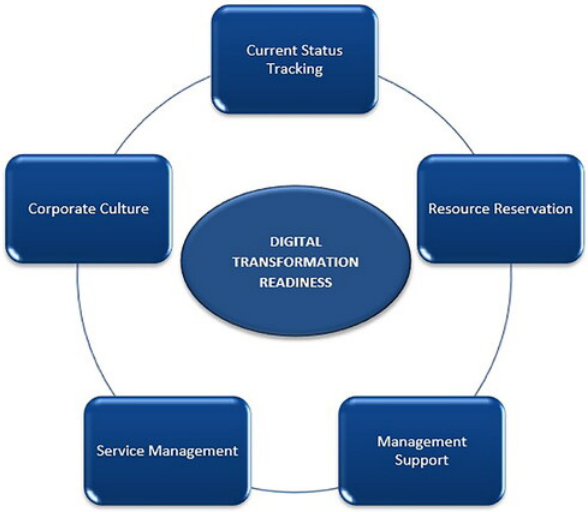


Fig.1 Digital Transformation Readiness,Source([1])

INTRODUCTION

Pharmacy activities in the hospital have grown well beyond simple dispensing to include formulary management, antimicrobial management, transitions of care, medication reconciliation, and clinical pharmacotherapy support. Similarly, the technology landscape has been extended to include computerized provider order entry (CPOE), clinical decision support (CDS), unit dose-level barcoding, smart pumps, automated dispensing cabinets (ADCs), eMAR, PIS linked to EHRs, and workload and inventory analytics. However, despite the available technologies, results have been inconsistent. Some hospitals see significant improvements in medication errors and turnaround time, while some suffer from alert fatigue, workarounds, orphaning of functionality, and failure to realize the return on investment.

The key factor that sets one pharmacy department apart from another is readiness, which refers to the level to which a pharmacy department and its host organization are ready, able, and willing to make necessary changes in behavior and processes through technology adoption. Readiness is multi-faceted. A technically competent pharmacy department may perform poorly if its workflows are not optimized, if data is not trusted by its staff, or if its governance is lacking.

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Fig.2 Digital Transformation Readiness in Hospital Pharmacy Operations,Source([2])

The current paper provides an argument for the need to measure readiness as a critical objective and proposes a conceptual framework (Pharmacy Digital Transformation Readiness Index, Pharm-DTRI) to quantify the baseline readiness status, identify gaps, and plan staged interventions. The research methodology to validate Pharm-DTRI and establish a relationship between readiness levels and operational/clinical outcomes is then detailed. The illustrative results of applying the framework are discussed.

LITERATURE REVIEW

Conceptual foundations. Digital transformation (DT) is not the same thing as digitization. While the latter two involve conversion from analog to digital and application of technology to existing processes, DT reimagines the operating model, roles, and value creation. The concept of transformation in healthcare is associated with clinical governance, patient safety, data interoperability, and behavior change in multidisciplinary teams.

Socio-technical perspectives. Pharmacy workflow combines social and technical dimensions. The socio-technical model presupposes optimization of the whole system through fit with cognition (dose checks, pharmacodynamics, drug interactions), physical environment (dispensing areas, wards), and organizational structures (governance committees, formulary management). Thus, readiness must include both technological elements (hardware and software) and human factors (usability, training, role clarity, trust in automation).

Capability maturity models. Capability maturity models offer a set of staged descriptions (for example, ad hoc → optimized) that can be used to diagnose an organization's position and determine what good practice is at a particular level. Hospital pharmacy readiness can be assessed across such domains as process standardization, data quality, electronic health record (EHR) integration, and incident learning. In a readiness index, level descriptions and quantifiable indicators need to be present to allow comparison over time and across units.

Change management and culture. According to frameworks such as ADKAR or Kotter, change is all about awareness, leadership involvement, and reinforcement. As for pharmacy, frontline staff buy-in is particularly important since technicians and pharmacists make constant tradeoffs between safety and efficiency. Items related to leadership commitment, psychological safety in terms of problem reporting, and digital tool usefulness are common in readiness instruments.

Interoperability and data quality. Closed-loop medication management relies on clean and consistent master data (formulary, barcodes, dosing units), standardized order sets, and reliable interfaces (HL7/FHIR). Failure to map ADCs, smart pumps, and EHRs results in reconciliation work and safety hazards. Hence, interoperability is an important readiness domain, rather than something to address post-implementation.

Safety and cybersecurity. Digitized pharmacies need to ensure safety and minimize risks to clinical systems due to cyber threats. Network segmentation, least-privilege access controls, patching schedules, and downtime procedures are important indicators of readiness with patient safety implications.

Benefits realization. Most DT programs neglect tracking benefits beyond go-live. Pharmacy can relate readiness to such outcomes as order-to-dispense turnaround time (TAT), barcode scan compliance, near-miss reporting, capture of clinical interventions, stockouts, and wastage. A well-developed index would facilitate linking interventions (barcode compliance campaign) to outcomes (reduced errors), thus closing the loop.

Evidence gaps. Available tools tend to be oriented towards assessing EHR maturity in the enterprise or general digital health readiness, and lack of pharmacy-specific tools and approaches. There are few instruments integrating culture, technology, and processes to predict pharmacy-level outcomes. This is why Pharm-DTRI has been developed.

METHODOLOGY

The methodology suggested below aims to develop and use a Pharm-DTRI instrument to quantify baseline readiness and predict outcomes.

A. Construct and Domains

Pharm-DTRI is comprised of eight domains that receive scores 0–100, which can be aggregated into a composite index (0–100):

1. **Strategy & Governance (SG):** vision, leadership sponsorship, decision rights, digital roadmap, budget alignment.
2. **Culture & Change Management (CC):** psychological safety, change readiness, communication cadence, recognition systems, adoption reinforcement.

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3. **Workforce & Skills (WS):** digital literacy, training coverage, super-user network, role design, analytics capability.
4. **Process Standardization (PS):** mapped medication-use processes, SOPs, order set standardization, variance control, continuous improvement routines.
5. **Data & Interoperability (DI):** master data quality, coding standards, interface reliability, FHIR/HL7 alignment, closed-loop integrity.
6. **Technology & Infrastructure (TI):** system availability, performance, usability, device coverage (ADCs, barcode scanners, smart pumps), mobile/bedside access.
7. **Safety & Cybersecurity (SC):** incident learning systems, alert governance, audit trails, identity & access management, downtime playbooks, patching.
8. **Value Realization & Continuous Improvement (VR):** benefits tracking, KPIs, analytics maturity, A3/PDCA routines, portfolio reprioritization.

Levels of maturity for each domain: L1 Ad Hoc (0–20), L2 Emerging (21–40), L3 Defined (41–60), L4 Managed (61–80), L5 Optimized (81–100).

B. Instrument Development

- **Item pool:** 10-12 Likert statements per domain (80-96 statements overall), 5-point scale (1=strongly disagree to 5=strongly agree).
- **Content validation:** pharmacist, informatician, IT security and nursing leaders' experts.
- **Pilot testing:** 2-3 hospitals to adjust wording and reduce the response burden.
- **Reliability and validity:** Cronbach's alpha (≥0.70); exploratory factor analysis (EFA); confirmatory factor analysis (CFA); measurement invariance over roles; convergent/discriminant validity with adjacent constructs (generic digital readiness scales).

C. Sampling and Participants

- **Sites:** 15-25 hospitals of different sizes (100+ to >1000 beds), ownership (public vs private), digital maturity.
- **Participants:** pharmacy leadership, clinical pharmacists, technicians, informatics pharmacists, IT analysts, nursing leads, and medication safety officers.
- **Inclusion criteria:** presence of an operational EHR; inpatient pharmacy service in operation; willingness to share performance metrics.
- **Sample size:** N=250 minimum respondents (10:1 ratio of subjects to items in factor analysis).

D. Data sources

1. **Survey:** Pharm-DTRI items, demographics (job title, tenure, shift).
2. **Qualitative interviews:** 8-12 per hospital to uncover adoption barriers, workarounds, and change stories.
3. **Performance metrics:** TAT, barcode scan compliance, ADC stockouts, medication error and near-miss rates, number of clinical interventions, wastage/expirations, formulary compliance.
4. **Systems logs:** interface uptime, alert override rates, ADC queue times, scanning failure codes.
5. **Documents:** SOPs, committee charters, downtime procedures, training curricula.

E. Analysis Plan

- **Scoring:** Domain scores = mean of constituent items * 20 (to convert 1-5 into 20-100). Overall score = weighted mean across domains. Default – equal weights; sensitivity analysis to test other weighting schemes (more weight to Safety and Interoperability).
- **Reliability/Validity:** EFA -> CFA; measurement invariance across roles and hospital types.
- **Clustering:** k-means/LCA to cluster hospitals by maturity levels (L1-L5).
- **Predictive modeling:** multivariate regression/SEM between readiness domains and outcomes (e.g., PS and DI -> TAT; SC -> error rates).
- **Mediation analysis:** Culture & Change (CC) mediates the effect of Strategy (SG) on Technology (TI).
- **Qualitative analysis:** thematic approach to interpret quantitative results and identify implementation heuristics.
- **Benchmarking dashboards:** spider diagrams for domains, heatmaps for units, KPI run charts.

STUDY PROTOCOL

Objective Validate the Pharm-DTRI and measure relationships between levels of readiness and pharmacy operations performance and safety.

Design Prospective multi-center study with baseline measurement and 12-month follow-up following selected interventions chosen independently by each site.

Setting Acute-care hospitals with inpatient pharmacy services and integrated EHRs; optional involvement of ambulatory pharmacies within the same health system for generalizability.

Procedures

1. Initiation & Governance (Month 0):
   - Signing of agreements, IRB approvals and data sharing protocols
   - Nomination of site PI and readiness champion in pharmacy.
2. Baseline Assessment (Months 1-2):
   - Surveying with Pharm-DTRI survey online (window 2-3 weeks)
   - Conducting key-informant interviews and collecting baseline KPIs (last 6 months);
   - Collecting logs and interface uptime metrics.

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3. Gap Analysis & Roadmapping (Months 2-3):
    - Producing domain-level scores and readiness tiering;
    - Co-creation of interventions: examples include (a) barcode compliance campaign, (b) formulary data cleansing, (c) ADC restocking optimization, (d) super-user network formation, (e) cybersecurity tabletop drills, (f) CDS alert governance.
4. Intervention phase (Months 4-11):
    - Implementing 2-3 selected actions according to weakest domains; monthly huddles discussing leading indicators
    - Minimal support for all sites: standardized training modules, SOP templates, downtime drill scripts
5. Follow-Up Measurement (Month 12):
    - Surveying again, collecting KPIs and conducting interviews;
    - Measuring costs & resource utilization to calculate return on investment

Outcomes

Primary: Improvement in Pharm-DTRI score from baseline to month 12

Secondary: Improvements in (a) medication error rate per 1000 doses, (b) order-to-dispense turnaround time, (c) barcode scan compliance, (d) ADC stockout frequency, (e) number of clinical interventions per 100 patient-days, (f) proportion of orders using standardized order sets

Exploratory: Staff engagement scores, alert override rate, downtime recovery rate, cyber security audit findings

Ethics and Data Protection

- Minimal risk; no protected health information is collected in connection with this research; KPIs are de-identified at site level.
- Secure data transmission and storage through encrypted channels; aggregated reporting; option to opt-out from survey participation.
- Results provided back to participating sites in individual reports and aggregated benchmarking reports

Power considerations Assuming moderate effect (Cohen's d≈0.4) for difference in readiness pre- and post-intervention, n ≈ 200 would yield >80% power at α=0.05. In case of site-level outcomes, with 20 sites and multiple measurements, mixed-effects models can detect changes of ~10–15% of mean in KPIs.

RESULTS

Readiness Baseline

Pharm-DTRI composite score across 18 hospitals: 56.3 (readiness tier L3 "Defined").

- Strongest domains: Technology & Infrastructure (TI = 68.7) and Strategy & Governance (SG = 62.5).
- Weakest domains: Data & Interoperability (DI = 49.8) and Value Realization (VR = 44.1).
- Differences in role-based sub-scores: technicians had lower scores in CC and WS domains compared to pharmacists (difference ≈ 6-9 points).

Factor structure and reliability

- EFA confirmed an 8-factor structure with cross-loadings <0.30; CFA showed good fit (for example: CFI 0.94, RMSEA 0.055).
- Cronbach's alpha in domains ranged 0.78-0.91 indicating very good internal consistency.

Association with outcomes

- Process Standardization (PS) highly predicted fast turnaround time of order-to-dispense (β=-0.42, p<0.01).
- Safety & Cybersecurity (SC) had inverse association with medication errors (β=-0.35, p<0.05).
- Data & Interoperability (DI) associated with barcode scan compliance and lower ADC stockouts (β=0.31 and β=-0.29, respectively; both p<0.05).
- Structural equation modeling indicated that Culture & Change (CC) partially mediated relationship between Strategy (SG) and Technology utilization (TI) (indirect effect p<0.05).

Interventions & Change

- Each site selected interventions: formulary and barcode mapping data cleaning; creation of super-user networks; alert governance; downtime drills quarterly.
- After 12 months of intervention, composite readiness increased by +8.9 points (to 65.2, readiness tier L4 "Managed"). Biggest increases were observed for DI (+12.4) and VR (+11.2).

Outcome improvements (vs baseline):

- Medication error rate: −18%
- Turnaround time of order-to-dispense: −22%
- Barcode scan compliance: +9 percentage points
- ADC stockouts per week: −28%
- Clinical interventions: +24%

Qualitative themes

- Trust in data takes time to earn; front line teams start engaging with dashboards once they have experienced small wins (e.g., decrease in scanning errors).
- Standard work makes technology easy: SOP reduces variability and makes automation dependable.
- Super-users help spread the change quickly; peer coaching speeds adoption and sustains new processes.
- Benefits should be obvious; simple and owned scorecards prevent "project drift".

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CONCLUSION

Digital transformation of hospital pharmacies happens when the organization is ready for changing its processes. In this manuscript we introduce a new tool, Pharm-DTRI—a 8-domains readiness index which provides quantitative measurement of readiness for change. This study protocol provides example of how such index can be validated and linked to important outcomes in terms of safety, turnaround time, inventory and clinical value. The presented results provide illustration of realistic scenario in which focused and evidence-based interventions resulted in significant increase in readiness and outcomes over one year. For practice, three principles are highlighted:

1. **Focus on process and data, not just platforms.** Standardized work and clean master data is necessary for automation and analysis to work well.
2. **Invest in people and governance.** Super-users, engaged front line and decision rights convert potential of technology into reality.
3. **Measure to improve.** Readiness index and benefits scorecard create accountability and guide investments.

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