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Organizational Readiness, Technology Integration, and Managerial Capabilities for Biotechnological Innovation in Saudi Pharmaceutical Companies

Randa Al-Madah*

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Abstract

Biotechnological innovation in pharmaceutical companies is often discussed as a problem of technology access, investment, or adoption, although organizational conditions determine whether technologies can be integrated into regulated workflows and converted into repeatable organizational capability. This article develops a non-empirical organizational-capability framework for interpreting biotechnological innovation in Saudi pharmaceutical companies through three analytically separate but interacting domains: organizational readiness, technology integration, and managerial capability. Organizational readiness is defined as a technology-specific configuration of strategic attention, workforce competence, learning capacity, resource availability, quality-system preparedness, and cross-functional coordination rather than as a static maturity score. Technology integration is distinguished from technology availability by emphasizing interoperability, data lineage, process ownership, validation requirements, and quality-system compatibility. Managerial capability is conceptualized as the ability to sense relevant technologies, translate technological possibilities into strategic priorities, mobilize complementary resources, allocate accountability, and reconfigure implementation when conditions change. The proposed Readiness–Integration–Capability Configuration Framework further distinguishes exploration, pilot, scaling, and routinization states while preserving feedback, organizational constraints, and external regulatory or ecosystem dependencies. The framework is intended as a theory-building architecture rather than an empirically validated prediction model. Its implications include technology-specific readiness assessment, integration-first investment planning, role-specific workforce development, explicit managerial decision rights, and stronger coupling between external partnerships and internal absorptive capacity. Future research should validate the framework longitudinally across heterogeneous Saudi pharmaceutical organizations.

Keywords: Organizational readiness, Biotechnological innovation, Pharmaceutical industry, Technology integration, Managerial capability, Saudi Arabia

Nemer Alotaibi*
Department of General Subjects, College of Business Administration, University of Business and Technology, Jeddah, Saudi Arabia.

***E-mail:** r.almadah@ubt.edu.sa

Introduction

Biotechnological innovation increasingly intersects with digital transformation, automation, advanced analytics, artificial intelligence, digital twins, process analytical technologies, data-intensive quality systems, and digitally connected manufacturing. Evidence synthesized across digital-transformation research indicates that organizational outcomes depend on multiple technological, organizational, and environmental antecedents and that the magnitude and direction of those relationships vary substantially across contexts (Dat *et al*., 2025; Lin, 2025). A pharmaceutical company may therefore possess technically advanced infrastructure without possessing the organizational capacity required to use that infrastructure effectively.

Digital transformation itself is not equivalent to technology acquisition. It involves strategic responses, structural adaptation, changes in value-creation pathways, and continuing organizational reconfiguration (Vial, 2019). Conceptual precision is consequently essential. Digitization, digitalization, and organization-level digital transformation describe analytically different states (Gong & Ribiere, 2021). Conflating them can produce an adoption narrative in which the presence of technology is treated as evidence of transformation, while the organizational conditions required for implementation remain unexamined.

Strategy and organizational-change research also emphasizes that digital transformation alters organizational structures, coordination mechanisms, and ecosystem relationships (Hanelt *et al*., 2021). These observations are particularly relevant to pharmaceutical biotechnology because implementation occurs inside regulated technical systems. A technology may be scientifically promising but organizationally unusable if it cannot be connected to validated processes, governed data, quality responsibilities, competent personnel, and accountable managerial decisions.

Saudi evidence provides additional reasons to avoid technology-centric interpretations. Stakeholders involved in real-world evidence for pharmaceutical regulation and market access have reported barriers involving data governance, local capabilities, resources, and institutional coordination (Sukkarieh *et al*., 2025). A Saudi multi-stakeholder analysis of the rare-disease and orphan-drug ecosystem likewise identified coordination and capability challenges spanning industry, regulators, healthcare institutions, academia, and public-sector actors (Abozaid *et al*., 2025). These

studies do not measure biotechnology readiness inside pharmaceutical manufacturers, but they reveal institutional conditions within which pharmaceutical innovation must operate.

Saudi implementation evidence from large-scale electronic health records further demonstrates that technological deployment can be constrained simultaneously by interoperability, infrastructure, training, technical support, user engagement, and leadership continuity (Alzghaibi & Hutchings, 2025). Electronic health records differ materially from biopharmaceutical technologies, yet the comparison is useful because it demonstrates locally that technical availability, organizational integration, and implementation capability are separable.

The central argument of this article is therefore that biotechnological innovation should be interpreted as a configuration problem rather than an acquisition problem. Organizational readiness, technology integration, managerial capability, workforce competence, quality-system integration, cross-functional coordination, and external ecosystem fit must be distinguished before their relationships can be meaningfully analyzed.

Defining Organizational Readiness for Biotechnological Innovation

Organizational readiness should not be defined as a generalized willingness to innovate (Asif & Shahbaz, 2025). Research examining digital transformation through dynamic managerial capabilities identifies multiple readiness-related conditions, including leadership, organizational culture, learning, stakeholder alignment, resource mobilization, and technological preparedness (Wang *et al*., 2026). Although this evidence derives from another industry, it demonstrates why organizational readiness should be decomposed rather than represented by a single undifferentiated construct (Dat *et al*., 2025).

Regulated pharmaceutical manufacturing adds additional conditions. A Pharma 4.0 case study documents an organization progressing through paperless processes, digital data collection, analytics, and related technological changes while still experiencing regulatory and operational constraints (McDermott *et al*., 2024). The implication is that technological advancement can coexist with incomplete readiness. A manufacturer may possess sophisticated equipment while lacking the integration, governance, competence, or change capacity needed to embed that equipment throughout the organization.

Emerging-market research conceptualizes digital readiness through technological sensemaking, agility, and implementation capability (Pingali *et al*., 2023). These dimensions should not be transplanted directly into Saudi pharmaceutical measurement without validation, but they reinforce an important distinction: organizations must first interpret technological relevance, then mobilize an appropriate response, and finally execute implementation. Technology possession alone captures none of these processes.

The distinction also changes across transformation states. Research differentiating digitization, digitalization, and broader transformation shows that different stages impose different strategic and organizational demands (Verhoef *et al*., 2021). Intellectual capital similarly does not automatically produce transformation effectiveness; organizational agility can mediate the conversion of resources into organizational action (Gong & Ribiere, 2025). Process research further suggests that transformation may cycle through exploration, scaling, optimization, and sustaining states, with different barriers and capabilities emerging at different stages (Yao *et al*., 2026).

This article therefore defines organizational readiness for biotechnological innovation as a technology-specific and state-dependent configuration of organizational conditions sufficient to permit responsible movement toward a subsequent implementation state. Readiness is not assumed to be additive. A company cannot necessarily compensate for deficient data governance by increasing executive commitment, nor can extensive workforce training compensate indefinitely for incompatible legacy systems.

The multidimensional and state-dependent nature of readiness is difficult to recover from prose alone. **Figure 1** therefore represents readiness as a configuration field containing interacting organizational layers, transition gates, and failure corridors rather than as a linear maturity ladder.

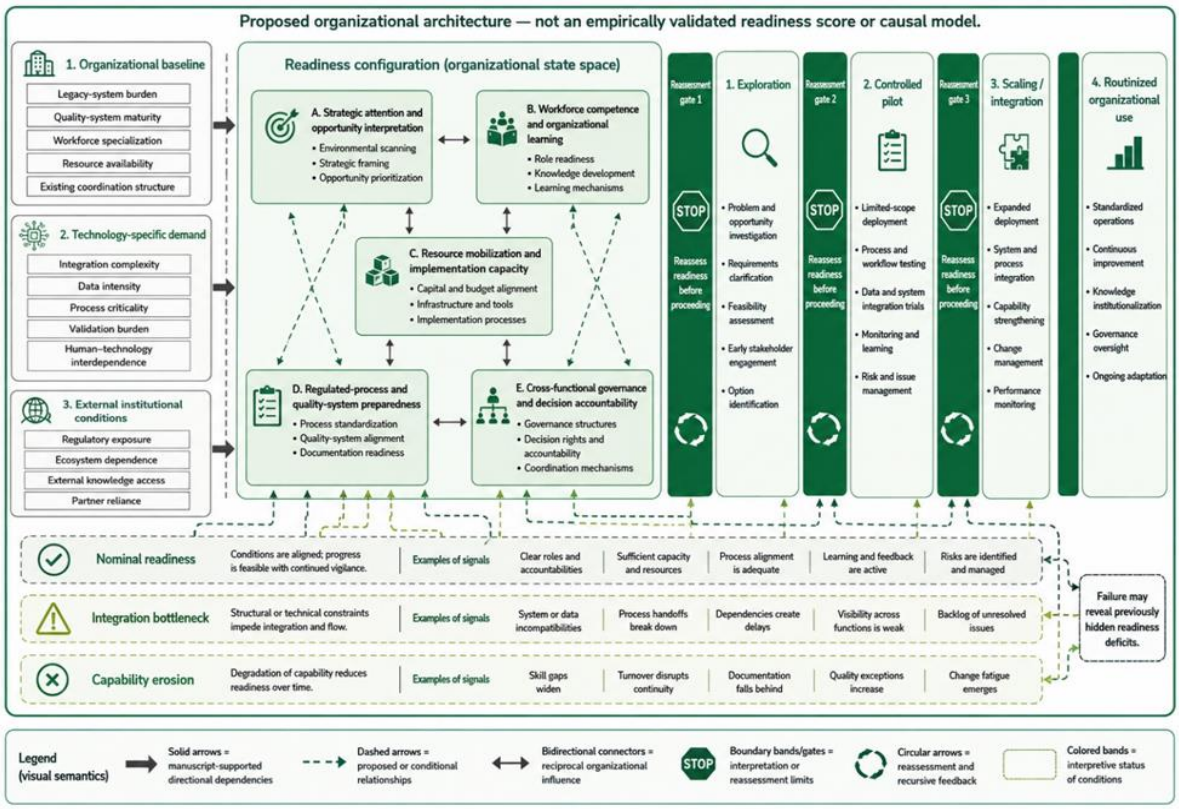

Figure 1. Readiness state-space for biotechnological innovation: organizational layers, transition gates, and failure corridors

Technology Infrastructure and Integration Capacity

Technology infrastructure defines what an organization could potentially use; integration capacity determines what the organization can actually embed into controlled work. Multi-firm transformation research identifies technology, data, people, processes, and organizational structure as complementary enablers rather than independent inputs (Gillani *et al*., 2024). Different combinations produce different transformation archetypes, which makes a universal infrastructure checklist inappropriate.

Socio-technical research on digital twins and digital threads similarly demonstrates that technical systems interact with organizational mindset and human capability (Ghosh *et al*., 2025). Technological infrastructure can therefore be technically mature while organizational integration remains weak. In biotechnology-intensive pharmaceutical environments, this distinction becomes more consequential because technical outputs may influence regulated processes.

Pharmaceutical and biopharmaceutical digital-twin research identifies applications across discovery, development, manufacturing, and continuous-production environments but also emphasizes data-integration, model-validity, and regulatory challenges (Maharjan *et al*., 2025). Integration capacity should consequently include the ability to connect analytical and process systems without compromising data integrity, model governance, traceability, validation responsibilities, or controlled decision-making.

Legacy organizational logic can constrain this process. Research on digital transformation and business-process management shows that established process-management assumptions may conflict with the flexibility required by digital systems (Baiyere *et al*., 2020). Pharmaceutical legacy burden may therefore exist not only in software but also in batch documentation, validation logic, equipment interfaces, data ownership, organizational responsibilities, and inherited process boundaries.

Information governance provides another distinct integration layer. Big-data analytics capability interacts with information-governance arrangements, and the relationship between analytics and innovation varies according to how information is controlled and managed (Mikalef *et al*., 2020). External integration also remains contingent. Industry 4.0 technologies may strengthen some collaborative relationships while weakening or failing to improve others (Kim & Park, 2024). Connectivity is therefore not an intrinsically desirable endpoint.

Technology classes also impose different managerial and organizational requirements (Mucaj *et al*., 2025). Evidence from healthcare managerial-support processes indicates that artificial intelligence, Internet of Things platforms, blockchain, and related technologies differ in their organizational applications and support needs (Mauro *et al*., 2024). The specific healthcare rankings cannot be imported into pharmaceutical manufacturing, but the analytical principle is relevant: infrastructure requirements must be matched to technology function rather than generalized under one "digital readiness" category.

Table 1 therefore maps the interfaces at which technological availability can fail to become organizationally usable capability.

Table 1. Integration dependencies that separate technology availability from usable biotechnological capability

Enabling interface	Receiving organizational system	Integration-to-control chain	Accountable owner	Failure diagnostic
Connected bioprocess or manufacturing equipment	Production, engineering, maintenance, and validation environment	**Integration dependency →** Equipment-to-process information exchange **Control/quality touchpoint →** Equipment status, controlled changes, process records	Operations with engineering and quality participation	**Failure state —** Equipment functions technically but remains isolated from controlled workflow **Readiness interpretation —** Technology availability without process integration
Advanced analytical or sensor platform	Laboratory and manufacturing-control routines	**Integration dependency →** Transfer of analytical output into operational decision processes **Control/quality touchpoint →** Data integrity, method governance, deviation and investigation processes	Scientific function with defined quality oversight	**Failure state —** Data generation exceeds organizational interpretation or governance capacity **Readiness interpretation —** Instrumentation exceeds organizational absorption
Digital twin or process-model environment	Physical process, engineering knowledge, and validated operating ranges	**Integration dependency →** Reliable synchronization between physical and virtual states **Control/quality touchpoint →** Model lifecycle, source-data provenance, change governance	Joint process, technical, and quality ownership	**Failure state —** Model becomes detached from current process or accepted decision boundaries **Readiness interpretation —** Model presence does not establish integrated capability
AI-supported analytical or decision system	Human professional decision workflow	**Integration dependency →** Machine output linked to accountable review and escalation **Control/quality touchpoint →** Training data, access control, review records, contested-output handling	Explicit managerial and technical decision owner	**Failure state —** Automated output exists without clear responsibility for action **Readiness interpretation —** Decision architecture is part of readiness
Integrated manufacturing or quality-data environment	Legacy repositories and documentation systems	**Integration dependency →** Cross-system interoperability and common identifiers **Control/quality touchpoint →** Traceability, master data, auditability, controlled access	Shared data, IT, operations, and quality responsibility	**Failure state —** Fragmentation, duplicate records, incompatible identifiers **Readiness interpretation —** Data architecture is an organizational dependency
External research, platform, or technology connection	R&D, innovation, technology-transfer, and partnership processes	**Integration dependency →** Internal absorption of externally generated knowledge **Control/quality touchpoint →** Qualification, intellectual property, data governance, transfer controls	R&D leadership with legal, quality, and data interfaces	**Failure state —** External connectivity exceeds internal evaluation or implementation capacity **Readiness interpretation —** Partnership volume cannot substitute for integration capability

Note. The table is a proposed analytical synthesis. The dependencies are not maturity levels, causal estimates, ranks, or validated organizational scores.

Managerial Capabilities and Strategic Alignment

Managerial capability should be distinguished from generalized leadership support. Dynamic-capability research describes digital transformation as repeated sensing, seizing, and transforming rather than a one-time investment choice (Warner & Wäger, 2019). For biotechnology innovation, managers must therefore interpret technological relevance, translate it into organizational priorities, mobilize complementary resources, establish decision rights, and reconfigure implementation when assumptions fail.

Industry 4.0 research similarly identifies portfolios of sensing, seizing, and reconfiguration capabilities required during transformation (Ostadi *et al*., 2024). This perspective is important because different managerial functions cannot be assumed to contribute equally. A firm may possess strong opportunity-recognition capability yet lack the resource-orchestration or cross-functional capability necessary to implement the opportunity.

Human–AI decision research further demonstrates that decision architecture depends on task characteristics, including originality,

reliability, transferability, and adaptability (Zhang *et al*., 2026). Managerial capability therefore includes allocating appropriate decision authority between automated systems and accountable professionals. Technology-centered interpretations that equate increasing automation with increasing capability overlook this governance function.

Longitudinal evidence from high-technology firms also suggests that digital transformation can be associated with innovation outcomes while the strength of those relationships varies by firm conditions (Xu *et al*., 2025). Managerial capability should therefore be interpreted as a conditional organizational mechanism rather than a guarantee of innovation performance.

Qualitative studies of small and medium-sized firms further show that sensing, learning, managerial cognition, social capital, and team-building capacity can develop during transformation (Matarazzo *et al*., 2021). Managerial capability is thus not necessarily fixed before technology adoption begins. Process research likewise demonstrates that managerial cognition and team structures may evolve as digital transformation progresses (Li *et al*., 2018).

Recent synthesis of digital innovation capabilities identifies multiple domains rather than one undifferentiated "digital capability" (Fan *et al*., 2026). AI-capability research reaches a compatible conclusion by conceptualizing organizational AI capability through combinations of tangible, human, and intangible resources (Mikalef & Gupta, 2021). These findings support a managerial action-state architecture rather than a generic leadership variable.

Table 2 distinguishes the managerial states through which technological opportunity is translated into accountable organizational action.

Table 2. Managerial action states connecting biotechnological opportunity with organizational implementation

Managerial function	Orient: opportunity recognition + organizational fit	Configure: resource mobilization + accountability design	Adapt and sustain: implementation reconfiguration + routinization stewardship
Sensing responsibility	**Opportunity recognition —** Detect technological, scientific, regulatory, or competitive relevance **Organizational fit interpretation —** Compare technology demands with existing organizational conditions	**Resource mobilization —** Identify deficits preventing implementation **Accountability design —** Identify decisions changed by the technology	**Implementation reconfiguration —** Detect emerging barriers during use **Routinization stewardship —** Detect drift, workarounds, competence erosion, or declining fit
Strategic translation task	**Opportunity recognition —** Determine whether the technology addresses a meaningful organizational problem **Organizational fit interpretation —** Specify where the technology belongs in the operating model	**Resource mobilization —** Convert strategic intent into sequenced capability requirements **Accountability design —** Define responsibility for technical outputs and regulated consequences	**Implementation reconfiguration —** Revise implementation without abandoning strategic purpose **Routinization stewardship —** Reassess whether the technology remains aligned with organizational priorities
Resource-orchestration requirement	**Opportunity recognition —** Commission technical and organizational assessment **Organizational fit interpretation —** Identify integration, competence, quality, validation, and governance deficits	**Resource mobilization —** Allocate personnel, infrastructure, expertise, funding, and external support **Accountability design —** Allocate decision rights, escalation routes, and review authority	**Implementation reconfiguration —** Recombine resources and modify routines as conditions change **Routinization stewardship —** Sustain competence, governance, maintenance, and organizational learning
Cross-functional coordination requirement	**Opportunity recognition —** R&D, operations, quality, technology, and regulatory functions jointly define the problem **Organizational fit interpretation —** Functions disclose incompatible assumptions and legacy dependencies	**Resource mobilization —** Resource owners coordinate rather than optimize isolated departmental priorities **Accountability design —** Scientific, quality, operational, data, and managerial roles remain explicit	**Implementation reconfiguration —** Operational feedback reaches managers capable of changing design **Routinization stewardship —** Continued coordination among operating and oversight functions
Change-management consequence	**Opportunity recognition —** Prevent novelty-driven commitment **Organizational fit interpretation —** Build a shared implementation rationale	**Resource mobilization —** Determine whether experimentation can progress beyond symbolic adoption **Accountability design —** Reduce ambiguity during human–technology handoffs	**Implementation reconfiguration —** Treat change as iterative **Routinization stewardship —** Prevent implementation from ending at technical go-live

Evidence boundary	**Opportunity recognition —** Recognition is not readiness **Organizational fit interpretation —** Strategic fit remains an organizational judgment	**Resource mobilization —** Resource commitment is not implementation effectiveness **Accountability design —** Governance enables controlled use but does not prove superior outcomes	**Implementation reconfiguration —** Reconfiguration capability does not ensure success **Routinization stewardship —** Continued use is not equivalent to demonstrated organizational benefit

Note. These action states are proposed conceptual distinctions. They should not be interpreted as empirically validated stages, additive capability scores, or causal determinants of biotechnology adoption.

Workforce Competence and Organizational Learning

Workforce readiness cannot be represented adequately by training counts. Workplace digital-skills research identifies multiple distinguishable dimensions, including technology use, cybersecurity, information management, communication, collaboration, critical inquiry, responsibility, well-being, and continuing professional development (Audrin *et al.*, 2024). Although the measurement instrument was not designed for Saudi pharmaceutical biotechnology, it demonstrates why competence should be role-specific rather than represented by one generic literacy score.

Industry 4.0 skill-gap research similarly identifies substantial inconsistency in how technological competence and skill deficits are defined and measured (Rikala *et al*., 2024). This limits the defensibility of universal capability checklists. A bioprocess scientist, process engineer, quality specialist, data steward, manufacturing operator, regulatory professional, and senior manager may interact with the same technology while requiring very different knowledge.

Organizational learning also extends beyond individual skill. Meta-analytic evidence on absorptive capacity indicates that innovation relationships vary with the knowledge environment surrounding the firm (Stettler *et al*., 2025). Consequently, capability development should include the ability to recognize external knowledge, assimilate it, transform it into organization-specific routines, and apply it under pharmaceutical quality and regulatory constraints.

For Saudi pharmaceutical companies, this implies that workforce development should be tied to the exact technology, workflow, decision responsibility, and implementation state. Early exploration may require scientific and strategic interpretation, whereas scaling may require broader operational, data-governance, quality, engineering, and change-management competence. Readiness should therefore be reassessed as the organizational distribution of competence changes.

Data, Process, and Quality-System Integration

Biotechnological innovation becomes organizationally consequential only when technical outputs enter controlled processes. Quality 4.0 research links digitally enabled quality-management practices with digital transformation and highlights the importance of organizational leadership and integration (Nguyen *et al*., 2024). This relationship does not demonstrate that digital quality practices will produce equivalent outcomes in Saudi pharmaceutical companies, but it reinforces the need to analyze technology and quality systems together.

Importantly, increasing digital maturity should not automatically be assumed to generate increasing innovation performance. Longitudinal evidence examining Quality 4.0 reports a nonlinear relationship with innovation in the studied firms (Deng *et al*., 2025). The specific functional form cannot be transferred to Saudi pharmaceutical organizations, yet the finding provides a crucial boundary against "more technology is always better" reasoning.

A regulated pharmaceutical company must therefore distinguish technical connectivity, process integration, quality integration, and decision integration. Technical connectivity exists when systems can exchange information. Process integration exists when information enters a defined operational workflow. Quality integration exists when provenance, review, change, and accountability remain controlled. Decision integration exists when outputs are connected to named professional or managerial responsibilities.

Figure 2 formalizes these distinctions as an integration-control architecture. Unlike **Figure 1**, which addresses readiness across implementation states, **Figure 2** concentrates on what happens once a technology attempts to enter the operational organization.

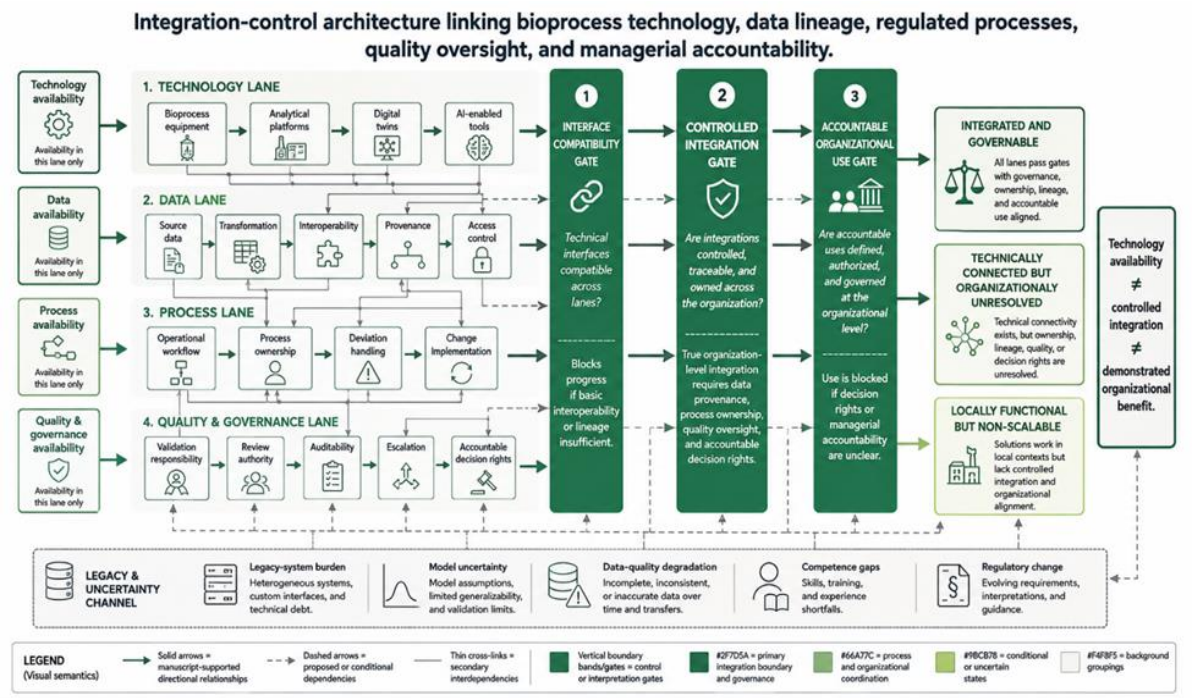

Figure 2. Integration-control architecture linking bioprocess technology, data lineage, regulated processes, quality oversight, and managerial accountability

Cross-Functional Coordination and Change Management

Digital transformation and innovation management operate across macro-, meso-, and micro-level processes that should not be collapsed (Appio *et al*., 2021). A biotechnology implementation may simultaneously alter individual tasks, team coordination, departmental responsibilities, quality governance, organization-level resource allocation, and external regulatory relationships. Treating these levels as one readiness variable obscures where implementation actually fails.

The broader management literature also remains heterogeneous rather than converging on a single universal transformation architecture (Kraus *et al*., 2022). This heterogeneity supports a configuration approach. Cross-functional coordination should not mean that every function participates equally in every decision; it means that interdependencies are identified before one function transfers unresolved implementation burdens to another.

Scientific teams may prioritize technological validity and novelty. Manufacturing may prioritize reliability and process continuity. Quality functions may prioritize controlled evidence, traceability, and accountability. Data and technology teams may prioritize architecture, interoperability, and security. Senior managers may prioritize strategic value, resource exposure, and timing. These priorities are not inherently incompatible, but neither are they automatically aligned.

The organizational problem is therefore one of handoff governance. Movement from opportunity recognition to technical evaluation, from pilot to regulated deployment, from data generation to accountable interpretation, and from initial implementation to routinized use should have identifiable owners. Feedback from later implementation states must also be capable of modifying earlier assumptions.

This approach treats change management as a continuing coordination capability rather than communication activity surrounding a fixed technological decision. It also preserves organizational heterogeneity. Large integrated manufacturers, smaller domestic producers, firms dependent on technology transfer, and companies pursuing selective biotechnology capabilities may require different coordination architectures.

External Ecosystem and Regulatory Fit

Internal readiness does not eliminate external dependency. Innovation intermediaries can improve awareness of technological opportunities and enhance knowledge acquisition, but their contribution to realized exploitation may remain limited where recipient firms lack internal absorptive capacity (Kerstens & Langley, 2025). This finding is highly relevant to biotechnology-intensive sectors, where external expertise can be substantial but organization-specific implementation remains internally governed.

Research on regional digital-transformation ecosystems similarly identifies brokerage, trust, strategic alignment, and knowledge exchange as important conditions influencing how external support is used (Marinelli *et al*., 2024). These mechanisms should not be transferred directly as validated Saudi pharmaceutical determinants, but they suggest that ecosystem access is valuable only when firms possess internal capacity to evaluate and integrate what they receive.

Saudi pharmaceutical organizations may depend on universities, technology providers, research centers, contract organizations,

global partners, regulators, and government innovation programs. These relationships can expand knowledge and technological access, but they may also introduce intellectual-property, qualification, data-governance, supply-dependency, and technology-transfer challenges.

External connectivity should therefore be distinguished from ecosystem fit. Ecosystem fit exists when external knowledge and resources are compatible with internal absorptive, governance, integration, and strategic capacities. A company with extensive partnerships but insufficient internal competence may remain externally connected yet organizationally unready.

A Readiness–Integration–Capability Configuration Framework

The preceding evidence supports a proposed Readiness–Integration–Capability Configuration Framework. The framework is not a validated readiness instrument, maturity score, causal model, or predictive algorithm. Its purpose is to organize distinctions that are routinely collapsed during technology-adoption discussions.

The first domain, organizational readiness, concerns whether the organization possesses a sufficiently compatible configuration of strategy, resources, learning capacity, workforce competence, quality preparedness, and governance to engage responsibly with a particular technology. Readiness is technology-specific and state-dependent. Conditions sufficient for exploration may be inadequate for regulated scaling.

The second domain, technology integration, concerns whether an available technology can enter technical, data, process, and quality architectures without leaving unresolved interfaces. Technology integration therefore includes interoperability, data lineage, process ownership, validation requirements, and accountable review.

The third domain, managerial capability, concerns the actions through which organizations interpret technological opportunities and alter their configuration. Managers sense, translate, mobilize, allocate responsibility, coordinate, and reconfigure. Managerial capability does not replace technical or workforce capability; it determines how heterogeneous organizational resources are orchestrated.

The framework therefore rejects a simple additive assumption. High scores in isolated domains should not be expected to compensate automatically for severe deficiencies elsewhere. Strong executive commitment cannot make incompatible systems interoperable. Extensive infrastructure cannot create professional judgment. Workforce expertise cannot by itself establish decision rights. External partnerships cannot substitute indefinitely for internal absorptive capacity.

The framework also rejects deterministic progression. Exploration, controlled pilot, scaling, and routinized use are analytically useful states, but organizations may move backward when integration failures, regulatory changes, workforce turnover, or hidden legacy dependencies emerge. **Figure 1** represents this recurrent reassessment. **Figure 2** shows why technical connection is only one component of organization-level integration.

The principal conceptual contribution is therefore to move from readiness as a static score toward readiness as a dynamic configuration of dependencies. The relevant question is not simply whether an organization is ready, but ready for which technology, at which implementation state, under which organizational and institutional conditions, and with which unresolved interfaces.

This distinction also defines the research agenda. Empirical validation should examine whether particular configurations are associated with movement between implementation states and whether the relative importance of readiness domains varies according to technology class, firm scale, ownership, legacy-system burden, process criticality, quality-system maturity, workforce specialization, regulatory exposure, or ecosystem dependence.

Capability-Building Priorities for Saudi Pharmaceutical Companies

The proposed framework suggests that capability building should begin with bottleneck diagnosis rather than generic maturity assessment. Pharmaceutical digitalization can progress unevenly even inside technologically engaged organizations (McDermott *et al*., 2024). Readiness assessment should therefore identify the dependency most likely to prevent movement into the next implementation state.

A second priority is integration-first investment planning. Technology procurement decisions should include data architecture, process ownership, quality-system interfaces, validation responsibilities, workforce implications, maintenance requirements, and decision governance from the beginning. A technology whose integration dependencies remain unresolved may create additional organizational complexity rather than usable capability.

A third priority is role-specific workforce development. Digital and biotechnological competence should be mapped to actual work rather than treated as a universal employee characteristic. Scientific interpretation, manufacturing operation, engineering integration, quality oversight, data stewardship, regulatory interpretation, and managerial decision-making require different capability combinations.

A fourth priority is managerial orchestration. Managers should be evaluated not only on support for innovation but on their ability to distinguish technological promise from organizational fit, mobilize complementary resources, allocate accountability, identify cross-functional bottlenecks, and revise implementation when evidence changes.

A fifth priority is quality-system integration early in adoption. Quality, validation, data integrity, and change-control implications should be incorporated before technologies become operationally embedded. Delayed integration increases the risk that technically functional systems develop outside the governance architecture required for reliable scale.

A sixth priority is ecosystem coupling with internal absorptive capacity. Partnerships, technology-transfer arrangements, universities, external research organizations, and specialized

vendors may accelerate access to knowledge, but external connectivity should be matched with internal evaluation and implementation capability.

Finally, capability building should be state-specific. Exploration requires strong opportunity interpretation and technical evaluation. Controlled pilots require integration planning and explicit accountability. Scaling requires broader workforce competence, robust quality-system integration, infrastructure reliability, and cross-functional coordination. Routinization requires learning, maintenance, monitoring, governance, and reassessment.

These priorities are proposed implications rather than tested Saudi interventions. Their value depends on future empirical studies capable of comparing organizational configurations and implementation trajectories across heterogeneous Saudi pharmaceutical companies.

Conclusion

Biotechnological innovation in Saudi pharmaceutical companies should not be interpreted primarily as a technology-acquisition problem. Organizational readiness, technology integration, managerial capability, workforce competence, quality-system alignment, cross-functional coordination, and external ecosystem fit represent distinct but interacting organizational conditions.

This article proposes a Readiness–Integration–Capability Configuration Framework that treats readiness as technology-specific, state-dependent, and configurational rather than as a universal maturity score. It separates technical availability from controlled integration and distinguishes managerial orchestration from generic leadership support. The framework also recognizes implementation failure, feedback, legacy constraints, regulatory conditions, and capability erosion as integral to organizational transformation.

The two proposed scientific figures formalize the article's principal analytical contributions: a readiness state-space containing transition gates and failure corridors, and an integration-control architecture separating technology, data, process, and quality/governance lanes. Together with the two article-specific tables, these structures convert the manuscript's conceptual argument into explicit, testable organizational relationships.

The framework remains non-empirical and requires validation. Future longitudinal research should determine which configurations facilitate or constrain biotechnology implementation across Saudi pharmaceutical companies and how these relationships vary by technology class, firm characteristics, quality-system maturity, regulatory exposure, workforce specialization, and external ecosystem dependence.

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