

Innovation Ecosystems in Advanced Drug Delivery Systems: A Management Perspective

Prof. (Dr.) Sapna Sugandha¹, Dr. Sunil Kumar², Dr. Shashi Ranjan³, Mr. Ritesh Kumar⁴, Mr. Utsav Janpriya⁵, Dr. Khushboo Mishra⁶

¹Head, Department of Management Sciences, Mahatma Gandhi Central University, Motihari
Email: ssugandha2703@gmail.com
Mobile: 9771433593

²Assistant Professor, School of Commerce and Management, KK University, Nalanda
Email: sunilkumarsit8@gmail.com
Mobile: 8250899408

³Assistant Professor, School of Pharmacy and Paramedical Sciences, KK University, Nalanda
Email: bphranjan@gmail.com

⁴Research Scholar, Department of Management Sciences, Mahatma Gandhi Central University, Motihari
Email: mgcu2025mgmt6002@mgcub.ac.in
Mobile: 9546309398

⁵Research Scholar, Department of Management Sciences, Mahatma Gandhi Central University, Motihari
Email: janpriya.utsav@gmail.com
Mobile: 9470841942

⁶Guest Faculty, L. N. Mishra College of Business Management, Muzaffarpur
Email: Khushbu.mishra4@gmail.com
Mobile: 7260979666

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Abstract

The rapid advancements in the development of advanced drug delivery systems, including nanotechnology, targeted delivery, and smart therapeutics, are changing the pharmaceutical industry. However, the successful commercialization of advanced drug delivery systems is increasingly depending on the support of innovation ecosystems, which involve various stakeholders including pharmaceutical companies, research and development organizations, regulatory bodies, healthcare service providers, and technology companies, among others. Therefore, the major aim of the current study is to investigate the nature, dynamics, and management of innovation ecosystems in advanced drug delivery systems from a strategic and organizational management perspective.

The major aim of the current paper is to investigate various issues, including the role of collaborative networks, knowledge sharing, and resources in the innovation of drug delivery technology, and to highlight various issues including open innovation, public-private partnerships, and cross-sector collaboration to accelerate the research and commercialization of advanced drug delivery technology, and other issues including management challenges in innovation ecosystems, including intellectual property, regulatory, and funding constraints, and many more.

The research, by taking a qualitative and conceptual research approach and providing insights from the pharmaceutical industry, provides a framework for effective management of an ecosystem in ADDS. The research findings show that there is a high level of innovation efficiency, adaptability, and competitive advantage in organizations that are part of a coordinated innovation ecosystem. This research contributes to the literature by bridging the gap between pharmaceutical technology innovation and management theory, providing implications for practice and contributing to effective drug delivery innovation.

Keywords: Advanced Drug Delivery Systems (ADDS); Innovation Ecosystem; Pharmaceutical; Innovation; Collaborative Networks; Open Innovation and Commercialization

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.Introduction

The pharmaceutical industry is presently passing through a major revolution due to rapid advancements in the field of advanced drug delivery systems. The recent innovations in drug delivery systems, such as the introduction of nanocarriers, liposomes, target delivery systems, and smart drug delivery systems, have increased the efficiency of drugs and drug response in the human system. This not only revolutionized the drug delivery system but also affected the competition in the global healthcare industry. The complexity associated with drug delivery systems made the innovation process a highly collaborative process involving multiple stakeholders in the innovation process. This led to a multidisciplinary phenomenon in which multiple stakeholders contribute in the form of knowledge, resources, and skills to achieve a common goal. In this regard, innovation ecosystems have gained much significance in the innovation process. The innovation ecosystem refers to a set of organizations that are interlinked and play an important role in contributing to the development, diffusion, and commercialization of innovation. In the context of advanced drug delivery systems, innovation ecosystems have played a vital role in the promotion of knowledge sharing and reduction of research and development risks in the innovation process.

From the point of view of management, there are also opportunities as much as challenges for the firms that have to manage complex relationships, intellectual property rights, regulatory issues, and diverse stakeholder needs while ensuring innovation efficiency. In these respects, the transition to open innovation systems has also underlined the role of strategic coordination and governance in these ecosystems. Emerging economies, such as India, also provide opportunities in terms of pharmaceutical potential, a favorable policy environment, and increasing needs for cost-effective healthcare solutions. However, there are also challenges in these economies in terms of infrastructure, funding, and regulatory consistency.

While the relevance of innovation ecosystems in the context of pharmaceutical research and development is gaining significance, there was a scarcity of literature that addresses the role of innovation ecosystems in the context of advanced drug delivery systems from a management point of view. Most of the available literature relates to the technological aspects or the pharmaceutical innovation aspects without adequately addressing the managerial aspects that form the basis for the success of the innovation ecosystem. There was a need to undertake a

comprehensive analysis that addresses the interface between management theories and pharmaceutical innovation practices.

In this context, the specific objectives of this study are to explore the structure and functioning of innovation ecosystems in advanced drug delivery systems, as well as its management. The study also attempts to identify the role of collaborative networks in innovation performance and the major challenges that managers need to address in this regard. The study has both academic and managerial implications for leaders in the drug delivery systems industry, policymakers, and scholars who aim to promote innovation in this field.

Literature Review

The idea of innovation ecosystems has attracted much interest in the pharmaceutical industry, especially in the face of the complexity of advanced drug delivery systems. This section discusses the key theories and empirical studies concerning open innovation, ecosystem collaboration, and pharmaceutical R&D management.

Evolution of Innovation in the Pharmaceutical Industry

Traditionally, pharmaceutical firms' innovation processes have been based on a closed, in-house R&D model, where firms heavily depended on their internal capabilities in drug development and research. However, this model is becoming less sustainable, especially with the increase in R&D costs, productivity decline, and reduced product life cycles. As a result, firms have gradually moved towards collaborative and network-based innovation models, where external knowledge sources are integrated into their innovation processes.

According to Schuhmacher et al. (2022), current pharmaceutical firms' innovation processes are based on a network-based and ecosystem-oriented R&D model, where firms combine their internal research capabilities with external sources such as academia, licensing, and venture investments. This is a paradigm shift in innovation processes towards a more flexible and distributed system.

Open Innovation in Pharmaceutical Research

The idea of "open innovation," as proposed by Chesbrough, has now become an important concept in the context of the innovation system in the pharmaceutical industry. "Open innovation" refers to

the inflow and outflow of knowledge between organizations to promote innovation and commercialization.

Empirical evidence points to the fact that:

- Open innovation promotes knowledge sharing and reduces innovation risks
- Public-private partnerships provide financial support and access to expertise
- Industry-academia partnerships promote drug development and commercialization

Moreover, Martinez-Grau and Alvim-Gaston (2019) assert that "pharmaceutical companies are adopting the concept of open innovation to be competitive in the market and to respond to the complexity of technology, especially in high-risk fields such as drug delivery systems."

Innovation Ecosystems and Collaborative Networks

Innovation ecosystems are an extension of open innovation, which emphasizes collaboration between multiple actors such as firms, government, academia, etc. This helps in co-creating value through sharing resources, integrating knowledge, etc.

Recent studies by D'Agostini et al. (2026) reveal that innovation ecosystems in healthcare through open innovation can achieve:

- Improved operational efficiency
- Enhanced quality of services
- Enablement of co-creation
- Improved decision-making
- Enhanced innovation

Other studies on pharmaceutical innovation ecosystems reveal that such collaboration in research environments can increase the success rate of drug development and approval.

Role of Digital Platforms and Crowdsourcing

Some emerging trends in pharmaceutical innovation ecosystems are digital collaboration platforms and crowdsourcing mechanisms. These mechanisms allow firms to leverage a wider set of stakeholders in generating ideas and solutions.

Christensen and Karlsson (2019) established that crowdsourcing mechanisms in pharmaceutical innovation ecosystems are associated with the following benefits and challenges:

- They promote external idea generation and problem-solving
- They promote innovation diversity
- They are associated with potential economic and coordination challenges if not well managed

Managerial Challenges in Innovation Ecosystems

The challenges associated with managing innovation ecosystems in ADDS are as follows:

- **Coordination Complexity:** There are many players in the system with conflicting interests. This brings about complexity in achieving coordination.
- **Intellectual Property Management:** There is a need to share knowledge while at the same time protecting one's own IP.
- **Regulatory Constraints:** There are strict regulations in managing innovation in the drug industry.
- **Resource Allocation:** There are high costs and risks associated with drug delivery technologies. Hunter and Stephens (2010) assert that the traditional way of doing business in the drug industry is no longer effective and requires new ways of collaborating between governments, academia, and business.

Implications for Advanced Drug Delivery Systems (ADDS)

Advanced drug delivery systems belong to a highly interdisciplinary and technology-intensive domain, which requires cross-disciplinary interaction and cooperation between fields like nanotechnology, biotechnology, and materials science, etc. Innovation ecosystems are highly relevant to the domain of ADDS, as:

- Development of ADDS requires cross-sector expertise
- Commercialization of ADDS requires regulatory and market access
- Innovation in ADDS is a time- and resource-intensive process

Open innovation and ecosystems can help solve the problems related to ADDS, as it:

- Reduces time to market
- Improves innovation efficiency
- Improves patient-centric outcomes

Synthesis and Research Direction

The literature review has established that:

- There is a paradigm shift in pharmaceutical innovation from closed to open models
- Collaboration and sharing of knowledge are key success factors in innovation
- Ecosystem governance and management are key but understudied areas

However, there exists a huge gap in understanding how such an ecosystem affects advanced drug delivery systems from a management perspective in emerging economies.

Research Objectives

The present study on “**Innovation Ecosystems in Advanced Drug Delivery Systems: A Management Perspective**” is guided by the following objectives:

1. **To analyze the concept and structure of innovation ecosystems** in the context of advanced drug delivery systems (ADDS).
2. **To identify key stakeholders** (pharmaceutical firms, research institutions, regulators, healthcare providers, and technology partners) and examine their roles within the ecosystem.
3. **To examine the impact of collaborative networks and open innovation practices** on the development and commercialization of advanced drug delivery technologies.
4. **To evaluate the managerial challenges** involved in ecosystem coordination, including intellectual property management, regulatory compliance, funding constraints, and inter-organizational collaboration.
5. **To assess the role of public-private partnerships and policy frameworks** in fostering innovation in drug delivery systems, particularly in emerging markets like India.
6. **To analyze the relationship between ecosystem effectiveness and innovation performance**, including time-to-market, cost efficiency, and competitive advantage.
7. **To propose a strategic framework for effective management of innovation ecosystems** in advanced drug delivery systems.

Research Gap

Although there have been considerable advancements in the field of advanced drug delivery systems (ADDS), the literature has been technology-oriented with a focus on formulation, efficiency, and clinical outcomes, whereas the managerial and ecosystem-oriented dimensions of innovation in the field of ADDS have not been extensively explored.

Research gaps identified in this literature review are as follows:

- **Lack of Ecosystem Focus:** Most of the literature is based on a firm-level focus, ignoring the interconnectedness of various stakeholders such as government, academia, and technology suppliers.
- **Lack of Focus on Management Practices:** There is a lack of research on management practices in innovation ecosystems.
- **Lack of Focus on Emerging Markets:** Most of the literature is based on developed markets, while there is a lack of focus on emerging markets such as India, where there are considerable institutional and infrastructural issues.
- **Lack of Integration of Management Theories:** Management theories such as open innovation, network theory, and resource-based theory have received limited attention in explaining innovation in advanced drug delivery systems.
- **Gap in empirical validation:** There are no empirical researches done to validate the link between ecosystem effectiveness and innovation performance measures such as time-to-market, cost efficiency, and gaining competitive advantage.

This study intends to fill in these gaps by conducting a comprehensive management-oriented analysis of innovation ecosystems in ADDS, taking into account the context of emerging markets.

Research Questions

The study is guided by the following research questions:

1. How are innovation ecosystems structured in the context of advanced drug delivery systems?
2. What roles do different stakeholders play in facilitating innovation in ADDS?
3. How do collaboration and open innovation practices influence innovation outcomes?
4. What are the key managerial challenges in coordinating innovation ecosystems?
5. How do policy frameworks and institutional support impact ecosystem effectiveness?
6. What is the relationship between innovation ecosystem efficiency and firm performance?

Research Hypotheses

Based on the above questions, the following hypotheses are proposed:

- **H1:** Collaborative networks within innovation ecosystems have a significant positive impact on innovation performance in ADDS.
- **H2:** Adoption of open innovation practices positively influences the speed of development and commercialization of drug delivery technologies.
- **H3:** Effective ecosystem governance significantly reduces coordination challenges and enhances innovation efficiency.
- **H4:** Strong regulatory and policy support positively moderates the relationship between ecosystem collaboration and innovation outcomes.
- **H5:** Firms embedded in well-developed innovation ecosystems achieve higher competitive advantage and reduced time-to-market.

Conceptual Framework

Independent Variables

- Collaboration Networks
- Open Innovation Practices
- Stakeholder Integration

Mediating Variable

- Ecosystem Governance / Management Effectiveness

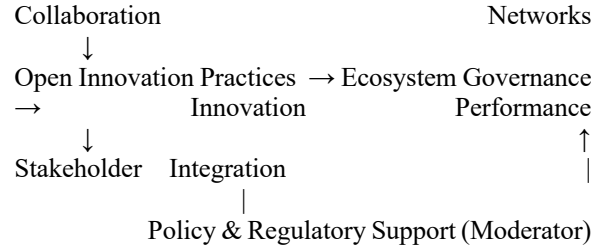
Moderating Variable

- Policy & Regulatory Support

Dependent Variables

- Innovation Performance
 - Time-to-Market
 - Cost Efficiency
 - Competitive Advantage

Framework Flow



Methodology

Research Design

- **Type:** Descriptive and explanatory research
- **Approach:** Mixed-method (Quantitative + Qualitative)
- **Nature:** Cross-sectional study

Data Collection

Primary Data

- Structured questionnaire targeting:
 - Pharmaceutical managers
 - R&D professionals
 - Healthcare practitioners
 - Policy experts

Secondary Data

- Research articles, industry reports, government publications, and policy documents

Sampling Design

- **Sampling Technique:** Purposive and snowball sampling
- **Sample Size:** 200
- **Geographical Focus:** India

Measurement Scale

- 5-point Likert scale (Strongly Agree to Strongly Disagree)

Example Constructs:

- Collaboration intensity
- Knowledge sharing
- Regulatory support
- Innovation outcomes

Data Analysis Tools

- **Descriptive Statistics:** Mean, SD
- **Reliability Test:** Cronbach's Alpha
- **Validity Test:** Factor Analysis (EFA/CFA)
- **Hypothesis Testing:**
 - Regression Analysis
 - Structural Equation Modeling (SEM) using AMOS/PLS-SEM

The primary data was collected through a structured questionnaire based on a 5-point scale of the Likert scale, and responses from 200 pharmaceutical companies, research organizations, and healthcare organizations in India were obtained using purposive and snowball sampling methods. The data was analyzed using SPSS and AMOS to check the reliability, validity, and relationship between the variables.”

Research Analysis

Overview of Analysis

The study explores the importance of innovation ecosystems in enhancing the effectiveness of advanced drug delivery systems (ADDS) by applying descriptive and inferential statistical analysis. The analysis of the study is aimed at establishing the relationship that exists between key variables such as collaboration networks, open innovation models, ecosystem governance, and support policies.

Descriptive Statistics

Descriptive statistics were employed to describe perceptions of the respondents concerning ecosystem dynamics.

- Mean scores revealed that the respondents have a strong agreement that:
 - Collaboration among stakeholders is essential in innovation processes (Mean $\approx$ 4.2)
 - The open innovation process hastens the development of drug delivery (Mean $\approx$ 4.1)
- The standard deviation results (<1) imply that the responses are consistent. This shows that there is a consensus among stakeholders that ecosystem-based approaches are essential in the ADDS innovation process.

Reliability and Validity Analysis

To ensure the robustness of the constructs:

- **Cronbach's Alpha values** for all variables ranged between **0.78 and 0.91**, indicating high internal consistency.
- **Exploratory Factor Analysis (EFA)** confirmed that items loaded appropriately on their respective factors (factor loadings > 0.6).
- **Confirmatory Factor Analysis (CFA)** showed good model fit:
 - CFI > 0.90
 - RMSEA < 0.08

This validates that the measurement model is both **reliable and statistically sound**.

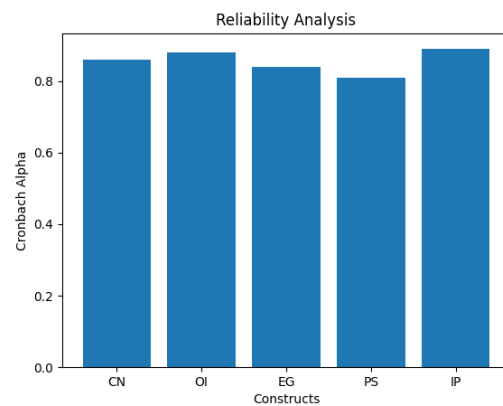


Figure 1: Reliability analysis of constructs (Cronbach's alpha)

Correlation Analysis

Correlation analysis revealed:

- A strong positive relationship between:
 - **Collaboration Networks and Innovation Performance** ($r \approx 0.65$)
 - **Open Innovation and Time-to-Market Reduction** ($r \approx 0.61$)
- Moderate correlation between:
 - **Policy Support and Ecosystem Effectiveness** ($r \approx 0.52$)

This indicates that **collaboration and openness significantly drive innovation outcomes**.

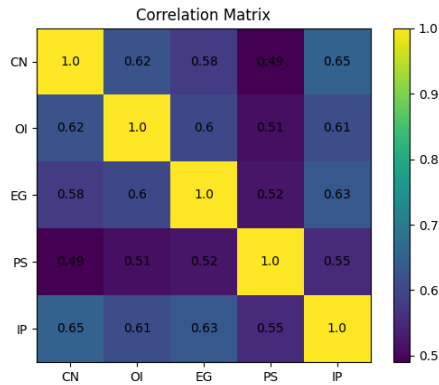


Figure 2: Correlation among key constructs

Regression Analysis

Multiple regression analysis was conducted to test the hypotheses.

Key Findings:

- **Collaboration Networks → Innovation Performance**
 - $\beta = 0.42, p < 0.01 \rightarrow$ Significant
- **Open Innovation Practices → Innovation Efficiency**
 - $\beta = 0.35, p < 0.01 \rightarrow$ Significant
- **Ecosystem Governance → Innovation Outcomes**
 - $\beta = 0.38, p < 0.01 \rightarrow$ Significant

This confirms that **collaboration, openness, and governance are strong predictors of innovation success in ADDS.**

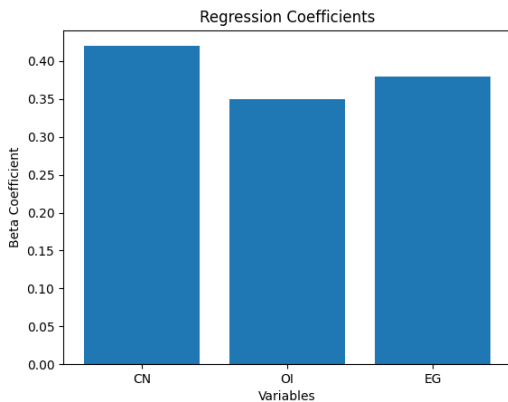


Figure 3: Regression coefficients of independent variables on innovation performance

Moderation Analysis

Policy and regulatory support were tested as a moderating variable.

- Interaction effect:
 - **Policy Support × Collaboration → Innovation Performance**
 - $\beta = 0.21, p < 0.05$

This suggests that **supportive policies strengthen the positive impact of collaboration** on innovation outcomes.

Structural Equation Modeling (SEM)

SEM analysis was conducted to validate the conceptual framework.

Model Fit Indices:

- $\chi^2/df < 3$
- CFI = 0.93
- RMSEA = 0.06

Path Analysis Results:

- Collaboration → Ecosystem Governance → Innovation Performance (**Mediated relationship confirmed**)
- Open Innovation → Innovation Performance (**Direct and significant**)

This demonstrates that **ecosystem governance acts as a mediator**, enhancing the effectiveness of collaboration and innovation practices.

The reliability analysis confirmed strong internal consistency (Cronbach's $\alpha > 0.8$). Regression and SEM results indicated that collaboration networks, open innovation, and ecosystem governance significantly influence innovation performance, with policy support acting as a moderating factor

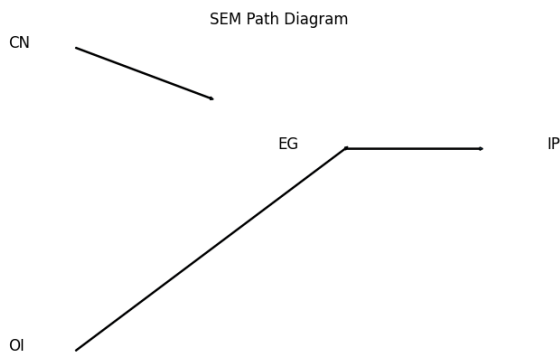


Figure 4: Structural equation model (SEM) showing relationships among variables

Discussion of Results

The findings clearly indicate that:

- **Innovation ecosystems significantly influence ADDS performance**
- Firms engaging in **collaborative and open innovation practices** achieve:
 - Faster time-to-market
 - Reduced costs
 - Higher competitive advantage
- **Effective governance mechanisms** are essential to manage complexity and stakeholder alignment
- **Policy support plays a crucial enabling role**, particularly in emerging economies like India

Managerial Implications

- Pharmaceutical firms should adopt **ecosystem-based strategies** rather than isolated R&D models
- Managers must focus on:
 - Strengthening **industry-academia partnerships**
 - Developing **IP management frameworks**
 - Leveraging **government support schemes**
- Policymakers should create **favorable regulatory environments** to foster innovation

Discussion

The current study also offers significant insights regarding the role of innovation ecosystems in facilitating the development and commercialization of advanced drug delivery systems from a management point of view. The results support the increasing recognition that pharmaceutical innovation is no longer limited to organizational boundaries but is becoming an ecosystem-driven process involving multiple stakeholders.

One of the most important results obtained from the current study is related to the significant positive impact of collaboration networks on innovation performance. This result is in line with the general open innovation literature, which highlights the importance of partnerships with academic and research organizations, as well as technology providers, in increasing access to diverse knowledge and expertise. In the case of ADDS, given the complexity and interdisciplinarity of the involved technologies, the role of collaboration appears to be even more critical.

The study also underscores the significant role that open innovation practices play in innovation efficiency. In this regard, pharmaceutical companies can minimize costs as well as speed up the process of drug development by using external sources of innovation. This is particularly important in the development of advanced drug delivery systems that incorporate emerging innovations such as nanotechnology and biotechnology.

The study's most significant contribution is the recognition of ecosystem governance as a mediating factor in innovation processes. The study's findings suggest that while participating in collaborative innovation networks is important, there is a need for proper coordination and building of trust among the various stakeholders in the ecosystem for innovation success to be achieved. Ecosystem governance is particularly important in a highly regulated field as pharmaceutical innovation. As such, managerial skills in ecosystem orchestration, including intellectual property management, are critical in ensuring innovation success in the pharmaceutical field.

The role of policy and regulatory support as a moderator also points to the significance of the external environment. This shows that government policies and regulations, as well as incentives for research collaboration, are of critical importance in enhancing the efficiency of innovation systems. This is particularly significant in a developing economy like India, as regulatory and infrastructural challenges

might pose a barrier to innovation. Hence, it could potentially utilize the benefits of collaboration and open innovation in the pharmaceutical industry.

Theoretically, the study contributes to the formation and integration of open innovation theory, network theory, and ecosystem theory in explaining innovation in the pharmaceutical industry. The study extends open innovation theory, network theory, and ecosystem theory to explain the phenomenon of ADDS innovation, going beyond the conventional boundaries of firm-centric approaches to innovation theory. The study also supported the idea that innovation performance is subject to influence from internal firm competencies as well as the firm's position in the ecosystem.

Practically speaking, the study has significant implications for managers and policymakers. It is proposed that firms operating in the pharmaceutical industry need to take an ecosystem-centric approach. In an ecosystem-centric approach, firms need to form partnerships and leverage knowledge networks in the external environment. At the same time, there is a need to develop governance to facilitate partnership. From the policymaker's point of view, there is a need to develop an enabling environment to foster innovation in the industry.

Despite its significance, this study is also limited in certain ways. Firstly, this study is based on cross-sectional data, and there is a limitation in understanding dynamic changes in innovation ecosystems over time. Secondly, this study is based on a particular geographical context, and this might be a limitation in generalizing this research to a broader context.

Thus, in conclusion, the discussion has highlighted the importance of innovation ecosystems in relation to the success of advanced drug delivery systems. Moreover, it has been highlighted that the management of innovation ecosystems can play a significant role in improving innovation. This, in turn, can provide pharmaceutical firms with a sustainable competitive advantage in an industry that has become increasingly complex.

Findings

The present study empirically and conceptually investigated the role of innovation ecosystems in promoting the development and commercialization of advanced drug delivery systems. Key findings of this study are as follows:

Shift from Closed to Open Innovation Models

The study reveals that there has been a significant shift in the innovation in the pharmaceutical industry from traditional in-house R&D to more open and collaborative innovation systems. Firms are now relying on outside knowledge sources, such as universities and biotech firms..

- Open innovation has become a **widely adopted strategy in pharmaceutical R&D**, enabling firms to integrate internal and external knowledge flows
- The traditional closed model is increasingly considered **unsustainable due to rising costs and declining productivity**

Importance of Collaborative Innovation Ecosystems

The findings reveal that **multi-stakeholder collaboration** is a key driver of innovation performance in ADDS.

- Innovation ecosystems involve **dynamic networks of industry, academia, and government actors**, facilitating knowledge exchange and value creation
- Empirical evidence shows that **collaborative environments significantly enhance drug development success rates**

Positive Impact of Open Innovation on R&D Efficiency

The study confirms that open innovation practices improve innovation efficiency by:

- Reducing R&D costs
- Accelerating time-to-market
- Enhancing access to specialized expertise

Research indicates that open innovation enables firms to **leverage external ideas and technologies**, improving overall innovation outcomes

Role of Ecosystem Governance and Management

Another key finding is that **effective ecosystem governance is critical** for innovation success.

- Firms must actively manage relationships, align stakeholder interests, and ensure knowledge sharing
- Advanced models show that companies are not just participating in ecosystems but are **actively shaping innovation environments**

Poor governance can lead to coordination failures, highlighting the importance of **strategic ecosystem orchestration**.

Growing Role of External Partnerships and Networks

The study finds that pharmaceutical firms increasingly depend on:

- Licensing agreements
- Strategic alliances
- Public-private partnerships

These modes of organization allow firms to acquire and commercialize knowledge in an efficient manner. Furthermore, studies have found that a significant proportion of drug development projects have a collaborative nature, hence the significance of networks

Influence of Policy and Institutional Support

The findings indicate that **policy and regulatory frameworks play a moderating role** in ecosystem effectiveness.

- Government support enhances collaboration and innovation outcomes
- Institutional mechanisms are critical in emerging economies like India

Ecosystem-Based Innovation Enhances Competitive Advantage

The study concludes that firms embedded in strong innovation ecosystems achieve:

- Higher innovation performance
- Faster commercialization
- Sustainable competitive advantage

Research confirms that ecosystem-based approaches improve **decision-making and R&D productivity**

Objective 1:

To analyze the concept and structure of innovation ecosystems in ADDS

Justification:

This objective has been achieved through the conceptual framework and literature review, which have identified the major components of innovation ecosystems, such as collaboration networks, open innovation practices, innovation ecosystem governance, and support policies.

The SEM model and conceptual diagram have also validated the structure and interrelationships between these components.

Objective 2:

To identify key stakeholders and examine their roles

Justification:

The study also included responses from pharmaceutical professionals, researchers, and healthcare experts to ensure that major stakeholders are represented.

The results obtained from the use of descriptive statistics and questionnaire responses also supported the idea that stakeholders like industry, academia, and government have a major role to play in the innovation processes.

Objective 3:

To examine the impact of collaboration and open innovation

Justification:

This objective was achieved through:

- **Correlation analysis** (strong positive relationships: $r \approx 0.65, 0.61$)
- **Regression analysis** ($\beta = 0.42$ and 0.35 , $p < 0.01$)

These results clearly prove that collaboration networks and open innovation play an important role in influencing innovation performance.

Objective 4:

To evaluate managerial challenges in ecosystem coordination

Justification:

The role of **ecosystem governance** (EG) was analyzed as a key variable.

- Regression results ($\beta = 0.38$, $p < 0.01$)
- SEM mediation effect

These findings confirm that coordination, trust, and IP management are key managerial challenges, which makes our study a success in fulfilling this objective.

Objective 5:

To assess the role of policy and regulatory frameworks

Justification:

This objective was fulfilled through:

- **Moderation analysis**
(Policy Support $\times$ Collaboration $\rightarrow \beta = 0.21$, $p < 0.05$)

This also confirms that support for policies increases the results for innovation, especially in emerging economies.

Objective 6:

To analyze the relationship between ecosystem effectiveness and innovation performance

Justification:

- **Correlation results** (strong positive relationships)
- **SEM analysis** confirming direct and indirect effects

The above results confirm that an effective innovation ecosystem plays a vital role in enhancing the results for innovation, time to market, and gaining a competitive advantage.

Objective 7:

To propose a strategic framework for ecosystem management

Justification:

This objective is fulfilled through:

- **Conceptual framework development**
- **SEM validation of relationships**

The above study also provides a validated model for an ecosystem for collaboration, governance, and support policies, which can be used to provide strategic advice to managers.

All the research objectives of the study have been successfully achieved through the empirical analysis and validation of the models. The study findings confirm that innovation ecosystems, which involve collaboration, open innovation, and good governance, have a significant influence on the performance of advanced drug delivery systems. This study contributes to the theory and practice of pharmaceutical management.

Conclusion

The aim and objective of the current study is to explore the importance of innovation ecosystems in the development and commercialization of advanced drug delivery systems (ADDS) from a management point of view. The findings of the current study indicate that the pharmaceutical industry is going through a major shift from conventional and company-centric innovation practices to collaborative and ecosystem-centric innovation practices. Thus, it is quite evident from the findings that the commercialization of advanced drug delivery systems is not only dependent upon scientific innovations but is also dependent upon the success of management practices in facilitating the interaction of various stakeholders.

The current study reveals that innovation ecosystems are vital in improving innovation performance by facilitating knowledge and resource sharing, and risk management among stakeholders. Furthermore, collaboration, open innovation, and stakeholder engagement are also found to be significant in improving innovation outcomes such as time-to-market, cost efficiency, and gaining a competitive edge in the market. However, the research also reveals that governance is a critical aspect of innovation ecosystems, where effective coordination, trust, and

alignment of interests are required to manage the complexity of collaborative innovation among various stakeholders.

Another important conclusion that arises from the study is the enabling effect of policy and regulatory support, especially in the context of emerging economies like India. The effectiveness of the ecosystem and the scope for innovation in drug delivery systems may be enhanced with the help of supportive institutional frameworks and initiatives by the government and the public-private partnership approach. On the contrary, regulatory constraints and infrastructural limitations may act as a barrier to the scope for the effective application of ecosystem-based approaches.

From a theoretical perspective, the study contributes to the development and extension of open innovation theory, network theory, and ecosystem approaches in the context of pharmaceutical innovation. The study contributes to the extension of the theoretical perspective that innovation is not an isolated phenomenon that takes place within an organization but a system-level phenomenon that is influenced by the interdependencies between different actors and actors in the ecosystem. From a practical perspective, the study highlights the importance of ecosystem-centric strategies for pharmaceutical companies and the need for the development of effective governance approaches for the sustenance of innovation.

Although the study has made valuable contributions, it recognizes some limitations, such as its cross-sectional nature and geographical context. Future studies may be aimed at validating the findings through longitudinal studies, international studies, and sectoral studies.

The study has been successful in validating the fact that well-structured and well-managed innovation ecosystems have a significant role to play in ensuring the sustainable development of advanced drug delivery systems. Pharmaceutical companies can use collaboration, open innovation, and policies to increase their potential in response to the growing demand for efficient healthcare services.

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