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AI-DRIVEN TARGET IDENTIFICATION: REVOLUTIONISING DRUG DISCOVERY IN INDIA'S BIOPHARMACEUTICAL INDUSTRY

By

SINDU SELVARAJ

A dissertation submitted in partial fulfilment of the requirements for the award of MSc in Digital Transformation (Life Science)

Innopharma Faculty of Pharmaceutical Sciences

Griffith College Dublin

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GRIFFITH COLLEGE DUBLIN

DECLARATION

Candidate Name: Sindu Selvaraj

I hereby confirm that the dissertation entitled AI-Driven Target Identification: Revolutionising Drug Discovery in India's Biopharmaceutical Industry, submitted in partial fulfilment of the requirements for the MSc in Digital Transformation (Life Science), is a research work conducted independently by me. All sources referenced during this research have been fully acknowledged through complete and accurate citations.

Candidate Signature: 

Date: 24/08/2025

Supervisor Name: Dr. Dinesh Reddy

Supervisor Signature: 

Date: 23/08/2025

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Finally, I acknowledge the unwavering support of my family and close friends, whose encouragement and understanding sustained my progress during this demanding academic undertaking. I remain deeply grateful for their belief in my aspirations and for the resilience this instilled in me.

Above all, I submit this work to the grace of God Almighty for blessing me with the strength and discernment that guided me through each stage of the research process.

SINDU SELVARAJ

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
NLP	Natural Language Processing
R&D	Research and Development
CDSCO	Central Drugs Standard Control Organisation
PDPA	Personal Data Protection Act
IIT	Indian Institute of Technology
IISc	Indian Institute of Science
CRO	Contract Research Organisation
GNN	Graph Neural Networks
HPC	High-Performance Computing

ABSTRACT

AI-Driven Target Identification: Revolutionising Drug Discovery in India's Biopharmaceutical Industry

Sindu Selvaraj

This study examined the impact of artificial intelligence (AI) on target identification in India's biopharmaceutical sector, specifically in the context of drug discovery. It looked at the degree of AI use, how it affects accuracy and efficiency, the main operational difficulties, how ready we are for new developments in AI, and how ethical and regulatory issues are currently being handled. A structured quantitative survey aimed at biopharma experts was used to gather data using a mixed-methods technique, which was bolstered by secondary analysis of industry changes. Results showed that although big companies like Biocon and Dr. Reddy's Laboratories are pushing AI integration, small and medium-sized businesses are still not adopting it at a high rate because of talent, infrastructure, and budgetary constraints. AI applications have been demonstrated to drastically cut down on discovery timeframes and increase target prediction accuracy in digitally mature pharmaceutical firms. However, problems including scattered digital infrastructure, a lack of qualified professionals, and poor data quality still exist. Additionally, the industry lacks ethical standards and legal frameworks tailored to AI, which leads to ambiguity and inconsistent application. The study indicates that while AI has the potential to revolutionise early-stage drug discovery in India, methodical efforts are required to expand workforce development, enhance infrastructure, and create clear governance norms. These results provide valuable insights for academic institutions, industry executives, and policymakers seeking to promote the ethical, efficient, and inclusive use of AI in pharmaceutical research in India. India's biopharmaceutical industry must embrace AI technologies and cultivate an innovative environment to stay competitive on a global scale. Scalability is hampered by the lack of standardised frameworks to assess AI performance throughout the drug discovery process. The need for flexible regulatory frameworks and funding for interdisciplinary education will only grow as artificial intelligence develops. Opportunities for more research on explainability, AI training, and responsible algorithm deployment are highlighted in this work. By filling these gaps, India can become a pioneer in morally sound, AI-powered pharmaceutical development.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Artificial intelligence (AI) is revolutionising the global biopharmaceutical industry, particularly in drug development, by increasing the accuracy, speed, and cost-effectiveness of research. Target identification (Figure 1) is one of the most crucial stages and involves identifying the genes, proteins, or pathways linked to the onset of a disease (Singh Saini *et al.*, 2025). This phase is costly and time-consuming, and often leads to low success rates because it has historically relied on manual experimentation and trial-and-error procedures. Artificial intelligence (AI) technologies (Figure 2), such as machine learning (ML), deep learning (DL), and natural language processing (NLP), offer more efficient options by rapidly analysing massive genomic, proteomic, and clinical information to find possible therapeutic targets (Singh Saini *et al.*, 2025), (Garg, 2025), (Kant *et al.*, 2025). The United States and the United Kingdom have shown early success, moving AI-generated targets through trials at record speeds (Narayanan *et al.*, 2022).

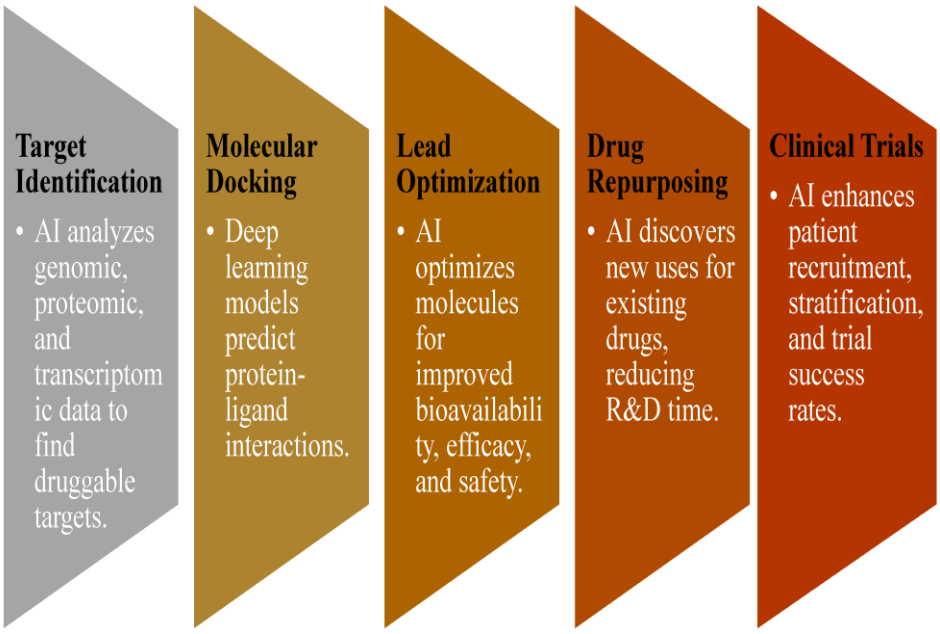

Figure 1. AI-Driven Workflow in Drug Discovery (Odah, 2025)

illustrates AI-accelerated drug discovery from target identification to clinical trials, improving speed, accuracy, and outcomes.

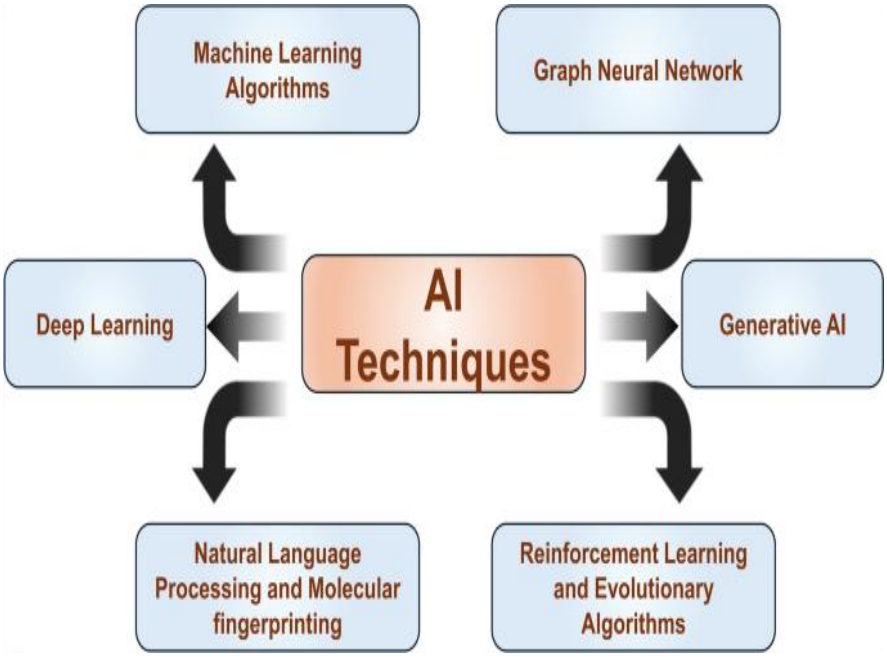

Figure 2. Artificial Intelligence Techniques in Drug Discovery (Kant et al., 2025)

illustrates that AI techniques like deep learning and generative models drive innovation in drug discovery and molecular research.

India's biopharmaceutical industry has not yet fully adopted AI for drug research, despite having a robust generic medicine and IT sectors (Ramani, 2014), (Goswami *et al.*, 2023). Though adoption is still modest, companies such as Biocon and Dr. Reddy's have started AI-driven projects. NASSCOM (2024) reports that more than 60% are in pilot stages (NASSCOM, 2024). Regulatory ambiguity, skill limitations, infrastructure deficits, poor data quality, and reliance on Western-trained datasets that are inappropriate for India's diverse population are some of the main obstacles (Singh *et al.*, 2024).

AI in drug research becomes not only advantageous but also essential. The rapid development of tailored medications for India's heterogeneous population, made possible by AI-driven approaches, can help address the nation's pressing healthcare problems (George, 2024). Given the intensifying global competition and rising research and development costs, Indian biopharmaceutical companies must shift from being just producers to being innovators. This study begins with the crucial stage of target identification and examines how AI might catalyse that transformation (Radhika Ktp, 2024).

1.1 Background of the Study

In the biopharmaceutical industry, artificial intelligence (AI) is revolutionising drug discovery, particularly during the critical and resource-intensive phase of target identification (Bhat *et al.*, 2025). The process of bringing a single drug to market (Figure 3), which has historically relied on hypothesis testing and trial-and-error techniques, can take more than ten years and cost billions of dollars (Sarkar *et al.*, 2023). The speed, accuracy, and cost-effectiveness of identifying therapeutic targets are greatly increased by artificial intelligence (AI) tools like machine learning (ML), deep learning (DL), and natural language processing (NLP), which allow for the quick analysis of large amounts of genomic, proteomic, and clinical data (Ravishankar, 2025), (Kant *et al.*, 2025).

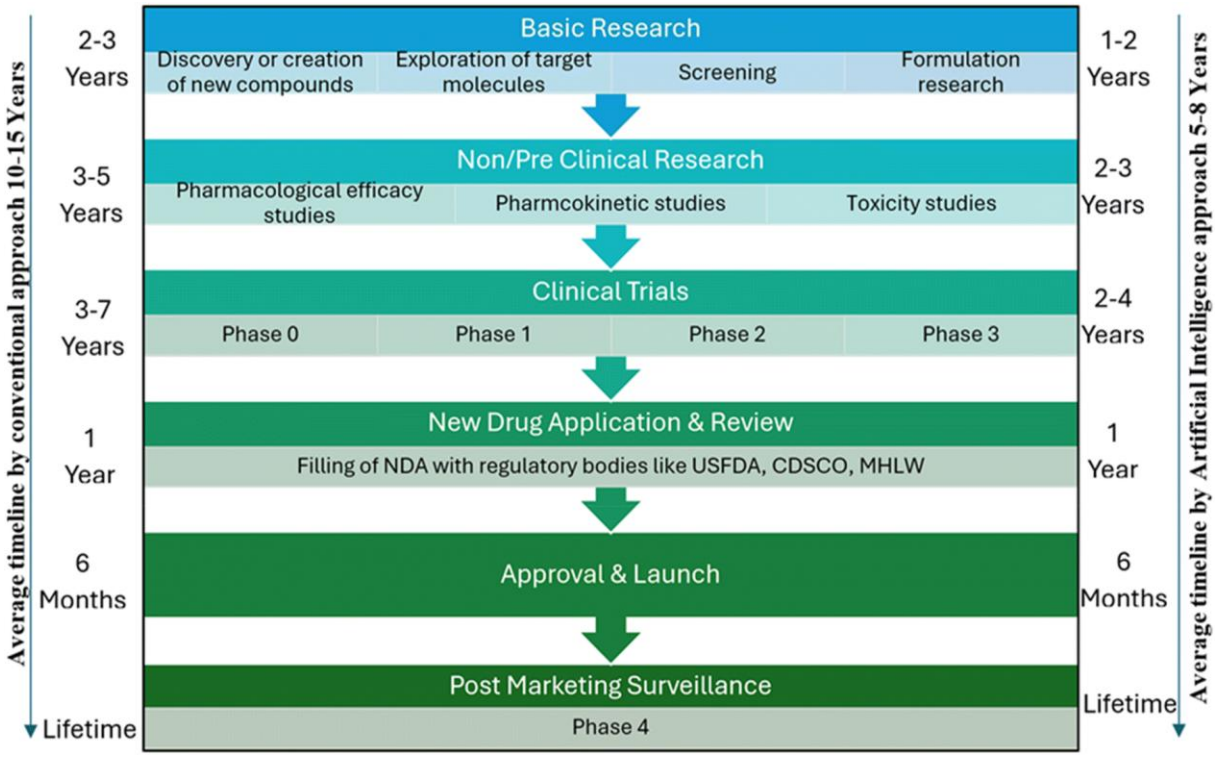

Figure 3. The comparative representation of how AI can impact drug discovery and approval processes in terms of timelines for different key steps (Singh Saini et al., 2025)

India's biopharmaceutical industry is still in the early stages of using AI for target identification, despite having a strong IT infrastructure and a global reputation in generic drug manufacturing. According to the NASSCOM 2024 report, more than 60% of the Indian biopharmaceutical

sector is still in pilot stages (NASSCOM, 2024). Data quality issues, regulatory ambiguity, infrastructure gaps, and a lack of qualified professionals are some of the main obstacles (Kimta, 2024). Furthermore, the majority of AI models are trained on information from Western datasets, which raises concerns about how accurate they will be for India's genetically diverse population (Nikhil Kasukurthi, 2025). To bridge this innovation gap and maintain its competitiveness in the global market, India needs to implement AI initiatives that are specific to its healthcare environment (Figure 4) (Anjali Raja, 2024).

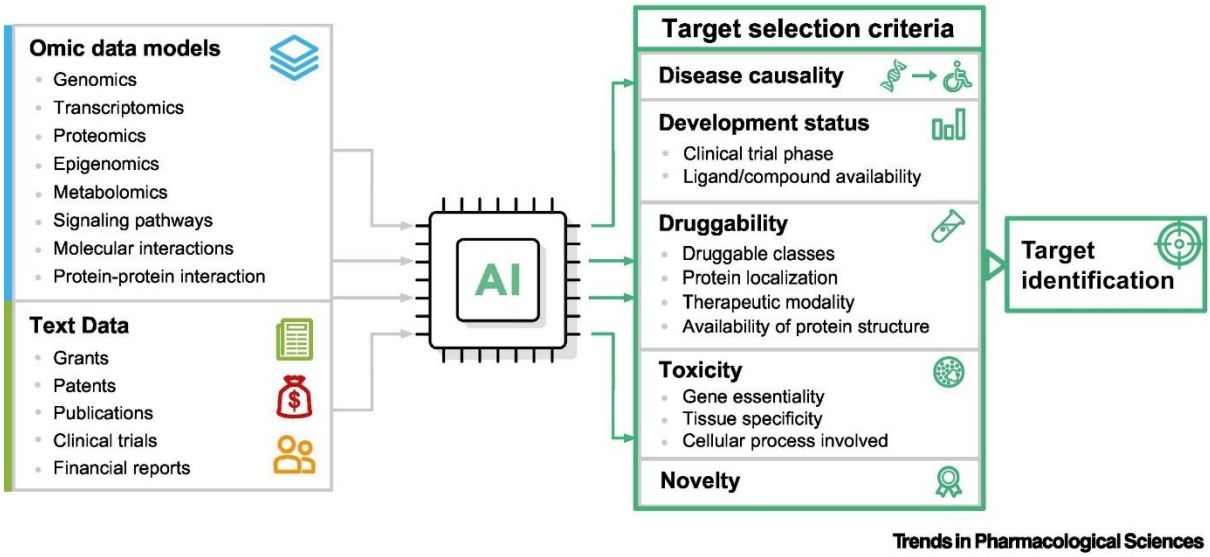

Figure 4. The emergence of Artificial Intelligence (AI) in early development (Pun et al., 2023)

1.2 Hypothesis

This study is based on the hypothesis that AI-driven target identification, unlike traditional methods, greatly improves the precision and efficiency of drug discovery in India's biopharmaceutical industry. It also suggests that while AI can reduce research time and costs, its success depends on overcoming challenges such as poor data quality, infrastructure limitations, and regulatory gaps. This research examines the use of AI in biopharma through both quantitative surveys and qualitative case studies.

1.3 Purpose of the Study

This study examines the effective, accurate, and inclusive use of AI for target identification in the biopharmaceutical sectors in India. It uses a mixed-methods approach, combining

challenges to identify current gaps and opportunities that can benefit academic research and industry practices.

1.4 Context of the Study

India's biopharmaceutical industry is renowned globally for producing generic medications, but it lags behind nations like the US and China in leveraging AI to discover novel drugs(Lata Harish et al., 2025), (Singal, 2025). More than 60% of the Indian pharmaceutical industry is still in the pilot stage, and obstacles, including poor infrastructure, poor data quality, unclear regulations, and a lack of skilled professionals, limit development (Research and Markets, 2024). By improving target identification, strategic AI integration presents a timely chance to boost innovation and global competitiveness (Amguth Raju, 2024), (Radhika Ktp, 2024).

1.5 Significance and Justification of the Study

The research topic, AI-driven target identification in India’s biopharmaceutical industry, is related to the module Big Data Acquisition and Management in the Digital Transformation (Life Science) program. AI-driven drug discovery relies on data collection, storage, and analysis, which are the main focus of this module. Optimising AI-driven target identification requires an understanding of big data management, as AI in biopharmaceuticals relies on large-scale biological datasets, machine learning models, and predictive analytics. Additionally, the Data Visualisation and Storytelling module may connect to the research topic because AI-driven drug discovery needs efficient data interpretation and visualisation to identify therapeutic targets.

1.6 Aims and Objectives

Research Aim

This study aims to explore how AI-based target identification could transform drug discovery in India's biopharmaceutical industry by improving the precision, accuracy, and cost-effectiveness of early-stage drug development.

Research Objectives

- Evaluate AI adoption in India’s biopharmaceutical Industry
- Assess AI’s impact on the Accuracy and Efficiency of Drug Discovery
- Identify Technical and Operational Challenges
- Explore Future AI advancements for Target Identification
- Evaluate Regulatory and Ethical Considerations

1.7 Research Questions

a. How widely is AI being used for target identification in India's biopharmaceutical industry?
b. How does AI-driven target identification affect the accuracy, efficiency, and cost-effectiveness of drug discovery compared to traditional methods?
c. What are the main technical and operational challenges that Indian biopharmaceutical companies face in implementing AI for target identification?
d. How can emerging AI technologies like deep learning, generative models, and quantum computing influence the future of target identification in India?
e. What regulatory, ethical, and data privacy considerations impact the integration of AI in target identification within the Indian biopharmaceutical context?

1.8 Overview of the Dissertation Structure

The dissertation is structured into five chapters as follows:

Chapter 1: Introduction

Introducing the research topic, providing background and context of the study, and a hypothesis, and emphasising the significance and scope of the study, including the research aim, objectives, and questions.

Chapter 2: Literature Review

In the literature review, a thorough examination of current academic and commercial literature on AI in drug discovery is conducted, focusing on target identification, adoption patterns in India, challenges, emerging technologies, and ethical and regulatory issues.

Chapter 3: Research Methodology

Describes the mixed-methods approach, combining both qualitative case studies and quantitative surveys, along with the study design and its philosophical basis (pragmatism). It outlines data collection tools, ethical considerations, sampling methods, and data analysis techniques.

Chapter 4: Findings and Analysis

Explains and evaluates the findings from the collected quantitative and qualitative data, highlighting new trends and relating findings to the research objectives.

Chapter 5: Conclusions and Recommendations

Discusses the study's limitations, emphasises the key findings, and provides recommendations for industry participants and future research directions.

1.9 Definition of Key Terms

- **Target Identification:** The process of identifying molecular structures (such as genes or proteins) that contribute to an illness and that a novel medication might target (Rasul *et al.*, 2022).
- **Artificial Intelligence (AI):** A field of computer science that focuses on creating systems that can perform activities like data analysis, pattern recognition, and decision-making that normally need human intelligence (Narayanan *et al.*, 2022).
- **Machine Learning (ML):** A subset of artificial intelligence that makes predictions or choices without explicit programming by using algorithms to learn from data (Patne *et al.*, 2024).
- **Generative AI:** Sophisticated AI models that can simulate chemical reactions or create novel medicinal molecules, including Generative Adversarial Networks (GANs) (Blanchard *et al.*, 2021).
- **Quantum Computing:** A computing paradigm of the next generation that can solve intricate molecular simulations at speeds and accuracy that are significantly faster than those of traditional computers (Science, 2025).
- **Algorithm Bias:** The tendency of artificial intelligence (AI) systems to produce inaccurate results due to flawed model assumptions or biased training data (Alexander Jonker et al, 2024).

CHAPTER 2

LITERATURE REVIEW

2. LITERATURE REVIEW

Modern biomedical research has seen a revolution with the introduction of artificial intelligence (AI) into drug discovery, which holds promise for resolving the long-standing inefficiencies of conventional pharmaceutical development pipelines. Target identification, identifying the molecular structures linked to the progression of disease, is one of the most resource-intensive, time-consuming, and failure-prone early stages of drug discovery (Pun *et al.*, 2023). Machine learning, natural language processing, and systems biology have all advanced quickly, and artificial intelligence (AI) can now greatly improve this process' accuracy and speed (Decheng Huang et al, 2024), (Abhishek Sahu*, 2025).

India's biopharmaceutical industry, which ranks among the biggest globally in terms of volume, is gradually shifting away from its conventional emphasis on producing generic drugs and toward more innovative research and development. Investments in digital health technologies have been accelerated by government-backed programs, including Startup India and the National Biopharma Mission (imarc, 2025), (Santhosh Kumar, 2025). Nevertheless, despite this momentum, India's practical use of AI for tasks like target identification is still lacking, especially in comparison to its international peers in the US, China, and the EU (Radhika Ktp, 2024). Thus, it is crucial to have a thorough grasp of the adoption rate, difficulties, and environmental elements affecting AI-driven innovation in Indian biopharmaceuticals (Kimta, 2024).

This review of the literature discusses target identification and AI's role in improving the early stages of drug discovery. It examines AI's impact on productivity and cost-efficiency, as well as the current level of technology adoption and infrastructure in the country. The paper also explores ethical and legal concerns affecting AI use in India and highlights new developments in AI, including deep learning, quantum computing, and generative models.

2.1 Evaluating AI Adoption in India’s Biopharmaceutical Industry

2.1.1 Global Context of AI Adoption in Drug Discovery

Artificial intelligence has become more prevalent in pharmaceutical research worldwide, especially in areas like target identification. To aid in drug research, nations like China, the United States, and the United Kingdom have created sophisticated AI platforms (Dermawan and Alotaiq, 2025). Compared to conventional methods, these platforms analyse biological, chemical, and clinical data to find possible drug targets more rapidly and precisely. Around the world, there is a growing trend of using AI technologies to speed up, lower the cost, and

increase the success rate of drug development (MATTHEW PERRONE, 2024), (K.Z Szalay, 2023).

2.1.2 AI Adoption Landscape in Indian Biopharma

The biopharmaceutical industry in India is still in the early phases of implementing artificial intelligence. Despite its strong IT capabilities and position as a global leader in generic medicine production, India has yet to fully adopt AI-driven drug discovery tools. The majority of projects about AI are still in the pilot or proof-of-concept phase (Radhika Ktp, 2024), (Pharmacy PRO, 2025). AI technology has been introduced by a few major pharmaceutical corporations, mostly through internal innovation laboratories or partnerships. Nevertheless, the industry has not yet adopted the broad use of AI in research and development, particularly for target identification (EY Shape the future with confidence, 2025).

2.1.3 Barriers to Adoption in India

The slow adoption of AI in Indian biopharmaceutical companies is caused by a number of variables. Lack of sophisticated digital infrastructure is a significant problem, especially for small and medium-sized businesses (Edwards, 2025). Older technology, fragmented data systems, and restricted access to high-performance computing are problems for many organisations. Poor data quality and a lack of well-structured clinical and biological datasets pertinent to the Indian population are other major obstacles (Milan Stanly, 2024), (Equity Master, 2025). Additionally, it is challenging to develop and oversee AI solutions internally due to a lack of experts with a combination of data science and life sciences knowledge. Deterrents can include the expense of using AI and the uncertain return on investment, particularly for mid-sized businesses (Kimta, 2024), (The Economic Times, 2025).

2.1.4 Regulatory and Policy Challenges

There is currently no defined regulatory framework in India that is intended to facilitate AI in pharmaceutical research. Guidelines for digital health and medical devices exist; however, they don't apply to AI-based drug discovery procedures. This deters businesses from making significant investments in AI projects by generating ambiguity about compliance, data protection, and algorithm validation. Additionally, coordinated development has been slowed down by the lack of national-level AI-focused biopharma incentives or programs (The Economic Times, 2024), (Standard, 2024).

2.1.5 Comparison with Global Leaders

Compared to countries like the US and China, India's rise appears to be less coordinated and supported by policies. These countries have specific AI legislation, robust industry-academic ties, and governmental funding for AI-driven research. Their vast data ecosystems also help machine learning and predictive modelling (Busch *et al.*, 2025). India does not, however, have a national genomics database or an AI-ready health data infrastructure (Genome India, 2024), (ETGovernment,2025). This makes it more challenging for Indian companies to develop models that are therapeutically appropriate to the local population (Foreign Affairs Forum, 2025)

2.1.6 Research Gap and Justification

Despite AI's growing popularity in Indian biopharma, not much research has been done to evaluate its effects and actual acceptability, especially in the target identification sector. Most of the currently published material either focuses on particular case studies or explores theoretical possibilities (Kimta, 2024). The extent of AI's applicability, the biopharmaceutical sector encountered the challenges, and the resources needed to increase its use all need further investigation (Singh Saini *et al.*, 2025). To close that knowledge gap, this study combines quantitative and qualitative research approaches to examine current applications of AI and offer useful recommendations for improvement.

2.1.7 Adoption Trends Across Large Firms and SMEs

The research proposal examined the adoption of AI in India's biopharmaceutical sectors from a comprehensive perspective, highlighting both theoretical potential and industry trends. Incorporating real-world examples can strengthen the overview of the study. Leading Indian pharmaceutical companies, such as Biocon and Dr. Reddy's Laboratories, have started integrating AI into their R&D processes through internal innovations and partnerships (ETPharma.com, 2024). These examples show that, although AI adoption is growing among large corporations, most Indian SMEs are still slowly adopting the technology due to financial constraints, lack of technological infrastructure, and limited digital maturity. Highlighting this disparity demonstrates the fragmented nature of digital transformation in India's pharmaceutical industry and supports the argument that adoption is unequal (Radhika Ktp, 2024),(Hussain and Rizwan, 2024),(Ravishankar, 2025). The current study aims to systematically analyse the extent, reach, and challenges of AI adoption across different types

of organisations, emphasising the need for a more detailed investigation based on real-world observations.

2.2 Assess AI's Impact on the Accuracy and Efficiency of Drug Discovery

2.2.1 Limitations of Traditional Target Identification Methods

Conventional drug development techniques are based on hypothesis-driven experimentation, which frequently entails time-consuming, trial-and-error testing. These procedures lead to a significant failure rate during clinical development in addition to being costly and time-consuming. Inadequate data or a lack of biological understanding might make it difficult to identify disease-relevant molecular targets, which usually takes years (Hingorani *et al.*, 2019), (Davis, 2020). Additionally, the integration of large and multidimensional datasets, including proteomic, phenotypic, and genomic data, is constrained by conventional approaches (Hughes *et al.*, 2011).

2.2.2 AI as a Catalyst for Precision and Speed

Artificial intelligence opens up new possibilities by facilitating high-throughput, data-driven target identification techniques. Genes, proteins, and disease phenotypes can be found through the analysis of large biomedical datasets using machine learning algorithms (Sharma *et al.*, 2023). Based on risk profile and predictive modelling, this enables researchers to rank goals with a higher chance of success. When it comes to combining many data sources like medical records, academic journals, omics data, and chemical structures into a unified analytical framework, AI models are especially helpful (Pun *et al.*, 2023). Because of this, AI improves the accuracy of finding targets that are both druggable and biologically relevant (Wenteler *et al.*, 2024).

2.2.3 Improved Decision-Making and Predictive Power

In addition to automating procedures, AI systems assist researchers in making decisions. Predictive models can rate possible targets according to how likely they are to succeed in preclinical and clinical contexts. Before physical testing starts, deep learning algorithms can forecast toxicity profiles or side effects and mimic drug-target interactions. This enhances decision-making throughout the drug development process, empowering scientists to choose wisely which targets to pursue, alter, or drop (Sinha et al, 2025), (Ghosh *et al.*, 2024).

2.2.4 Application Gaps in the Indian Context

The advantages of artificial intelligence are widely known, but there is no proof that the biopharmaceutical sector in India has adopted it extensively. Only recently have Indian companies started investigating AI solutions for target identification, and the majority of the claimed improvements in accuracy and efficiency are still in the experimental stage (Chindhalore *et al.*, 2025). Furthermore, a large number of AI models utilised in India are modified from global systems, which could not function as well with local data because of variations in community genetics, disease prevalence, and environmental conditions. As a result, to fully utilise AI in enhancing drug development results, models tailored to India must be created and verified (Avik Sarkar et al, 2025), (Chettri *et al.*, 2025).

2.2.5 Need for Impact Evaluation and Local Evidence

There is a dearth of empirical evidence demonstrating how AI has directly increased accuracy, efficiency, or cost-effectiveness in Indian drug discovery, despite encouraging advancements (The Bharat Biz, 2025). The return on investment from AI efforts has not been consistently measured or reported by the majority of companies. As a result, a knowledge gap exists regarding the true operational impact of AI (Neetu Chandra Sharma, 2024). This study fills that gap by examining case study data and professional viewpoints to determine whether AI technologies are producing the desired results in the Indian environment.

2.2.6 Organisational Impact of AI on Drug Discovery Efficiency

AI has the potential to improve drug discovery's accuracy and efficiency, especially during the target identification stage (Paramasivan, 2021). Using examples from Indian companies, these theoretical advantages can be further contextualised to support the study. It has been claimed that Biocon Biologics has utilised AI in biosimilar development, employing predictive modelling to understand complex biologic behaviour, reduce formulation failures, and expedite regulatory compliance (Dr. Rajendra Pratap Gupta, 2025). Meanwhile, Dr. Reddy's Laboratories has implemented predictive modelling to shorten chemical design cycle times (Swati Bharadwaj, 2024). These early accomplishments imply that AI can significantly improve research precision and speed up medication development timeframes. Nevertheless, these deployments remain restricted to larger companies that possess adequate financial and digital capabilities. To fully realise AI's promise, many smaller businesses still rely on conventional discovery techniques since they lack access to the data ecosystems and qualified professionals needed (Amguth Raju, 2024). The research has a better basis for assessing how

well AI is improving results in the Indian biopharmaceutical market by connecting the theoretical advancements with this practical gap.

2.3 Identify Technical and Operational Challenges

2.3.1 Lack of High-Quality and Localised Data

The absence of relevant, clean, and standardised data is one of the most urgent technical obstacles to the use of AI in drug discovery. Large amounts of organised biological, clinical, and chemical data are necessary for the training of algorithms in effective AI systems (Blanco-González *et al.*, 2023), (Yadav *et al.*, 2024). A large portion of this data in India is either not digitised, not comprehensive, or presented differently by different institutions. There are not many public databases, and private companies frequently do not want to divulge confidential information (Sood *et al.*, 2025), (Equity Master, 2025). Furthermore, a lot of the datasets that are now accessible are derived from non-Indian populations, which limits their suitability for developing models that take into account the genetic and epidemiological variety of the nation (Barbosu, 2024).

2.3.2 Infrastructure Limitations

High-performance computing infrastructure, cloud-based data storage, and secure data pipelines are necessary for advanced AI systems (ETHealthworld.com, 2022), (Sindhuja Balaji, 2020). Access to these resources is limited for many Indian biopharmaceutical companies, particularly small and medium-sized businesses. Smaller businesses may have financial limitations and outdated technologies, whereas larger corporations may have specialized IT staff. In addition to slowing down the adoption of AI, inadequate infrastructure poses security and compliance issues. Without scalable platforms, pharmaceutical companies are unable to analyse or process data quickly enough for drug discovery (Amguth Raju, 2024).

2.3.3 Talent and Skill Gaps

The lack of experts in data science and pharmaceutical sciences is another significant operational issue. The use of AI in drug development is intrinsically multidisciplinary, necessitating knowledge of computer science, cheminformatics, bioinformatics, and regulatory affairs (Taylor, 2014), (Priyanka Pulla, 2014). Although there is a large pool of IT specialists in India, comparatively few of them have biomedical application training (Kulkarni-Kale *et al.*, 2010). On the other hand, the majority of researchers in the biological sciences lack programming skills in AI or machine learning. This disparity in talents hinders teamwork and

impedes creativity. Few universities provide integrated degrees that fill this knowledge gap, and there are few training options available (Vora *et al.*, 2023), (Gupta *et al.*, 2015).

2.3.4 Data Privacy and Governance Concerns

The incorporation of AI is further complicated by the lack of explicit laws about data usage, sharing, and protection. Complying with legal and ethical requirements requires cautious handling of proprietary formulas, genetic sequences, and sensitive patient data (Angela, 2024). Companies in India are faced with uncertainty on how to handle AI-driven research without infringing on privacy rights because data protection regulations are still developing. Particularly in regulatory contexts where AI-generated outputs are not yet entirely recognised as evidence, worries about algorithmic bias, a lack of transparency, and accountability contribute to additional hesitancy (The Economic Times, 2023), (Nishith Desai, 2023).

2.3.5 Fragmentation of Research Ecosystem

India has a fragmented research ecosystem with little cooperation between government agencies, business, and academia. This results in redundant work and slower advancements in AI. India's pharmaceutical research is still decentralised, in contrast to other nations that have set up channels at the national level for data integration and collaborative research. Industry-wide scaling of AI initiatives is hampered by the absence of shared AI models, open-access biomedical libraries, and coordinated R&D financing (Sender, 2025). (Kamble, 2025), (Rajvanshi, 2024).

2.3.6 Need for Holistic Assessment of Challenges

Many of these problems have been identified separately, but there is a lack of thorough studies that outline the entire range of operational and technical difficulties unique to India's biopharmaceutical industry (Business Standard, 2024)The majority of research that is now available is either theoretically oriented or has a worldwide emphasis. It is essential to understand how these challenges are experienced in practice, particularly from the perspective of experts actively involved in AI applications. To meet that requirement, this study collects first-hand information on the obstacles preventing AI from being used for target identification in Indian drug discovery settings (The Economic Times, 2025).

2.3.7 Differential Organisational Barriers to AI Integration

Adoption of AI in drug discovery is limited by operational and technological issues, particularly in the varied organisational structure of India's biopharmaceutical industry. Bigger

companies like Dr. Reddy's and Biocon have begun to fill infrastructure shortages by investing in digital labs, cloud platforms, and qualified interdisciplinary teams (Prathiba Raju, 2025). Many small and medium-sized businesses, on the other hand, still use outdated systems, fragmented datasets, and a lack of professionals who are knowledgeable in artificial intelligence. Further impeding growth are organisational silos, ambiguous digital strategies, and constrained R&D budgets (Kuldeep Bhalerao et al, 2025). Additionally, training and validating AI models are challenging due to the lack of standardised data formats and the dependence on paper-based or semi-structured information. These differences demonstrate that readiness for integrating AI is uneven. To create support plans, policy interventions, and capacity-building measures that are specifically suited to India's distinct pharmaceutical ecosystem, a thorough grasp of how technical and operational constraints differ throughout the industry is necessary (ETPharma.com, 2024).

2.4 Explore Future AI Advancements for Target Identification

2.4.1 Next-Generation AI Technologies in Drug Discovery

Advanced artificial intelligence (AI) technologies that transcend conventional machine learning are rapidly influencing the direction of drug discovery. Researchers' approach to target identification is evolving in response to cutting-edge technologies such as deep learning, generative models, and quantum computing (Zeng *et al.*, 2022). These developments enable more accurate descriptions of molecular interactions, more precise simulations of biological systems, and the rapid screening of potential drug targets (Braga and Rawal, 2025). It is anticipated that these technologies will increase success rates and significantly reduce the time required for early-stage medication development (Gangwal and Lavecchia, 2024).

2.4.2 Deep Learning for Target Prediction

In order to uncover intricate patterns from large biomedical datasets, deep learning, a type of machine learning, uses multi-layered neural networks. Integrating many data sources, including gene expression patterns, protein structures, and genomic sequences, is one area in which it excels (Chandra Gonesh et al, 2025). Deep learning algorithms can prioritise high-confidence targets, identify new mechanisms of action, and forecast genes linked to disease in target identification (Mathema *et al.*, 2023). In multi-omics investigations, where traditional approaches would find it difficult to handle the volume and complexity of data, these features are extremely helpful.

2.4.3 Generative Models for Novel Target Discovery

Generative models, such as variational autoencoders (VAEs) and generative adversarial networks (GANs), are being utilised more and more to mimic biological responses and create new chemical structures. These models can simulate how compounds attach to particular proteins, produce theories regarding unknown drug-target interactions, and even suggest completely new target candidates (ROY *et al.*, 2023). Their ability to generate new ideas makes them effective instruments for drug discovery, particularly in conditions with few available treatments. These models may be able to direct researchers toward biological pathways and targets that have not yet been investigated, as they develop (Nangia, 2023).

2.4.4 Quantum Computing in Molecular Simulation

A significant advancement in computing capacity is represented by quantum computing, which makes it feasible to simulate molecular dynamics at a level of detail that is not achievable with classical systems. Quantum computers can aid in target discovery by simulating protein folding, optimising binding affinities, and forecasting atomic-level structural changes (Paliwal *et al.*, 2023). Although it is still in its early stages, quantum computing has the potential to significantly increase target validation's accuracy and effectiveness. When finished, it might resolve the computational snags that impede drug development processes today (Srivastava, 2023).

2.4.5 India’s Position in Emerging AI Technologies

India has not yet become a global leader in developing next-generation AI for drug discovery. Even if the country's IT and pharmaceutical sectors are thriving, funding for advanced AI research, especially in the health sciences, is still lacking. Only a few Indian companies or academic institutions are now working on deep learning or generative models, especially tailored for biomedical applications (Mahipal et al, 2025). Furthermore, access to resources for quantum computing is restricted, and there are not many collaborative studies involving AI researchers and drug discovery experts (Ravishankar, 2025). If concentrated efforts are not taken, India could fall behind in the adoption of these revolutionary technologies.

2.4.6 Opportunities for Strategic Advancement

India has a great opportunity to benefit from upcoming developments in AI. A strong foundation for growth is provided by the nation's expanding biotech startup ecosystem, growing pool of AI talent, and interest in digital health innovation. If it has the right policies, infrastructure, and training programs, India could develop AI systems tailored to its specific

genetic, environmental, and disease-related challenges (Purav Gandhi, 2025). Future advancements, such as cloud-based drug discovery tools, open-access AI libraries, and interdisciplinary R&D labs, could position India as a leading pioneer in target identification (Monalisa Sethi, 2025).

2.4.7 Need for Strategic Foresight and Industry Readiness

Despite the rapid global use of advanced technologies, India must assess its readiness to incorporate them into biopharmaceutical research. There are not enough research papers on how the Indian pharmaceutical industries are preparing for the introduction of new technologies, or how they see their practical significance (Tirunagari *et al.*, 2024). This study aims to explore those perspectives to offer insights into the opportunities, objectives, and strategic initiatives that could help India future-proof its drug discovery capabilities.

2.4.8 India's Readiness for Advanced AI Technologies

Target identification in drug research could be revolutionised by emerging AI technologies like deep learning, generative models, and quantum computing. These tools make it possible to analyse complex biological data, simulate pathways, and predict novel molecules at speeds that were previously impossible with traditional techniques (Odah, 2025). Leading pharmaceutical companies in India have started experimenting with these technologies, although there hasn't been much adoption of them yet. While Dr. Reddy's Laboratories has expressed interest in generative AI for novel therapeutics (Swati Bharadwaj, 2024), companies such as Biocon are using predictive modelling to understand complex biological behaviour to speed up regulatory compliance and reduce formulation failures, and also use AI in biosimilar development (Dr. Rajendra Pratap Gupta, 2025). However, because of obstacles like exorbitant prices, a lack of experience, and restricted access to high-performance computing, these developments have not yet reached the majority of the industry, especially SMEs. Significant concerns regarding inclusivity, scalability, and national competitiveness are raised by the discrepancy between domestic readiness and global innovation trends (Amguth Raju, 2024). To guarantee fair, future-ready innovation in pharmaceutical research, it is essential to comprehend how the Indian pharmaceutical sector views and prepares for these next-generation tools.

2.5 Evaluate Regulatory and Ethical Considerations

2.5.1 Regulatory Landscape for AI in Biopharmaceuticals

There are many regulatory issues when AI is used in medication research. AI-driven approaches, in contrast to traditional drug development procedures, frequently incorporate

data-driven outputs, automated decision-making, and dynamic algorithms that are challenging to validate through standard regulatory paths. Regulatory bodies throughout the world have begun creating frameworks to evaluate AI techniques used in drug research and healthcare. These laws are still developing, though, and vary by location. There are currently no thorough regulations in India that address the use of AI in pharmaceutical research and development. For organisations looking to develop or implement AI-driven target identification solutions, this creates uncertainty (Verma, 2023), (Ariffa, 2025), (Abinav Verma et al, 2020).

2.5.2 Ambiguity in Policy and Compliance

A major obstacle in India is the lack of established standards for data exchange, algorithm transparency, and AI evaluation. Although regulations about medical devices and digital health are slowly taking shape, they do not yet address the particular difficulties presented by artificial intelligence in drug research (Chettri *et al.*, 2025). Businesses are still unclear about how to obtain regulatory approval for AI-generated insights, particularly for tasks like candidate selection or target validation. Adoption and investment are delayed by this ambiguity, especially for smaller businesses that cannot afford the legal or regulatory risk of non-compliance (Kuldeep Bhalerao et al, 2025).

2.5.3 Data Privacy and Ethical Responsibility

Large volumes of sensitive data, such as genomic sequences, patient histories, and clinical trial results, must be accessible to AI systems used in drug discovery. There are significant ethical questions about data ownership, permission, and privacy when handling this data (Khalid *et al.*, 2023). There is currently no national framework in India that outlines precisely how biomedical data can be gathered, stored, processed, and shared for AI research, and data privacy laws are still being developed (Sengupta et al, 2024). Biased algorithms trained on non-representative data sets run the danger of breaches, abuse, or prejudice in the absence of stringent data governance procedures (Jeyaraman *et al.*, 2023), (Pham, 2025).

2.5.4 Algorithmic Bias and Equity Concerns

AI algorithms trained on incomplete or biased datasets may yield distorted findings in a country with the genetic and cultural diversity of India. If models are developed using different datasets that are not representative of the Indian population, there is a greater chance of inaccurate predictions and insufficient therapeutic application (Das *et al.*, 2024). This raises ethical concerns about fairness, inclusivity, and the right to effective and safe care. These biases could lead to the prioritisation of commercially viable targets above clinically urgent ones, or they

could result in the omission of high-risk populations during target identification (Joseph, 2025), (Norori *et al.*, 2021).

2.5.5 Accountability and Transparency in AI Decision-Making

Accountability is a crucial ethical concern in the context of AI in drug discovery. When an AI system suggests a molecular target or forecasts efficacy, it's frequently unclear who should confirm the outcome: developers, researchers, or regulatory bodies. Many AI models are black-box in nature, making it hard to explain how choices are made. This undermines transparency and confidence. The risk of relying too much on algorithmic results without enough human validation exists in the absence of adequate oversight (Singh *et al.*, 2025), (Auclair and Rathore, 2025).

2.5.6 The Role of Policy in Enabling Safe AI Deployment

National regulations must cover data protection legislation, algorithm transparency criteria, regulatory approval processes, and cross-border data sharing agreements in order to facilitate the ethical and safe application of AI in India's biopharmaceutical industry. While maintaining public safety and confidence, these regulations need to encourage innovation (Sapate *et al.*, 2025). To guarantee thorough assessment and knowledgeable supervision, it is also essential to train ethics committees and regulators on AI technology. Policymakers, academia, and industry must work together to develop flexible, forward-thinking regulatory frameworks that keep up with emerging technologies (Singh *et al.*, 2025).

2.5.7 Regulatory Uncertainty and Ethical Oversight in AI-Driven Drug Discovery

AI's incorporation into biopharmaceutical research presents serious ethical and regulatory issues, especially when it comes to data utilisation, decision transparency, and algorithmic responsibility (Mittermaier *et al.*, 2023). Although general data privacy rules are changing in India, there are still no well-developed frameworks for AI applications in drug research. Internal compliance procedures are followed by larger companies like Biocon and Dr. Reddy's, but they don't necessarily include ethical protections unique to AI. Smaller organisations frequently have less knowledge of or ability to apply these governance measures (Ravishankar, 2025), (Roychowdhury, 2025). There are still unresolved issues with informed consent for the use of secondary data, potential algorithm bias, and the inexplicability of AI predictions. Without national guidelines, organisations are left to interpret ethical standards in different ways, which puts them at risk for non-compliance, harm to their brand, and public mistrust. To encourage responsible innovation, strong regulatory frameworks and ethical supervision

procedures must be established. Closing these gaps will be essential to promoting AI use while upholding research integrity and public confidence (Tiana Hill, 2023), (Sood *et al.*, 2025).

2.6 Gaps and Justification for Further Research

Despite a growing global conversation about the moral and legal implications of AI in healthcare, there is still a noticeable lack of literature that focuses exclusively on the Indian biopharmaceutical sector. The majority of current research is conceptual, addressing theoretical implications or using case studies from other countries without considering India's unique ethical, operational, and regulatory contexts (Ravishankar, 2025). India has not yet established any guidelines or policies addressing the use of AI in drug discovery (Kant *et al.*, 2025). Pharmaceutical businesses in India are, therefore, confronted with a great deal of uncertainty regarding data security, compliance, and the validation of AI-generated outputs. The way the Indian pharmaceutical sector is interpreting and addressing these issues in practical contexts is not well supported by empirical data (Kimta, 2024).

Furthermore, in India's biopharma setting, important ethical issues such as algorithmic bias, data governance, patient consent for the use of secondary data, and transparency in AI decision-making are not sufficiently examined. These concerns are especially pertinent in light of the nation's heterogeneous population, fragmented data infrastructure, and changing privacy regulations. In the absence of ethical protections and locally specific legal frameworks, the deployment of AI runs the danger of worsening already-existing healthcare disparities or jeopardizing data integrity (Goswami *et al.*, 2023), (Das *et al.*, 2024). The study will evaluate the perceptions and responses of industry professionals to these ethical and regulatory issues by integrating qualitative and quantitative viewpoints.

2.7 Summary

Artificial intelligence is transforming drug discovery, especially in the resource-heavy target identification phase. Although AI has been adopted by global leaders in the biopharmaceutical industry to enhance precision, speed, and cost-efficiency, its adoption in India remains uneven and limited, with most programs still in the pilot stage. Indian companies still face challenges such as fragmented infrastructure, low R&D investment, a lack of cross-disciplinary knowledge, and limited access to high-quality data, despite the country's thriving IT and pharmaceutical sectors.

The importance of ethical and legal considerations is increasing, including population-specific model validation, algorithmic transparency, and data governance. While global models provide guidance, customised solutions are necessary for India's diverse healthcare system. Many questions remain about the exact impact of AI on decision-making, accuracy, and productivity. This study examines the application of AI, operational and ethical issues, and expert opinions on responsible adoption in Indian biopharma.

2.8 Conceptual Framework

This conceptual framework demonstrates how artificial intelligence (AI) impacts target identification in India's biopharmaceutical industry. It emphasises AI technologies like machine learning and deep learning as essential for enhancing the accuracy, efficiency, and cost-effectiveness of early-stage drug discovery. However, successful implementation depends on key factors such as data infrastructure, trained personnel, clear regulations, and ethical governance.

The concept explains how both enablers and constraints shape the complex relationship between AI and improved drug discovery outcomes. While issues like algorithm bias, poor data quality, or policy gaps may reduce AI's impact, factors such as organisational readiness, access to localised data, and regulatory support can speed up its adoption. By linking these ideas to the five study objectives, this model guides the research and helps interpret how technology, operational challenges, and policy interact in the Indian context.

Figure 5 illustrates the analytical framework for assessing AI-driven target identification in India's biopharmaceutical sector. The analysis depends on the Input factors, which include data infrastructure, organisational readiness, AI technology, and the ethical and legal environment. These are assessed alongside Mediators/Constraints that impact implementation success, such as algorithm bias, talent shortages, data quality, and regulatory clarity. The processes of AI adoption, integration, technical implementation, and workforce involvement show how inputs are turned into outcomes. The results improved accuracy, increased efficiency, and highlighted greater innovation, highlighting the measurable effects of AI adoption. A clear visual summary of the framework is provided by the graphic, emphasising the dynamic connections between operational procedures, moderating factors, enabling conditions, and the benefits achieved.

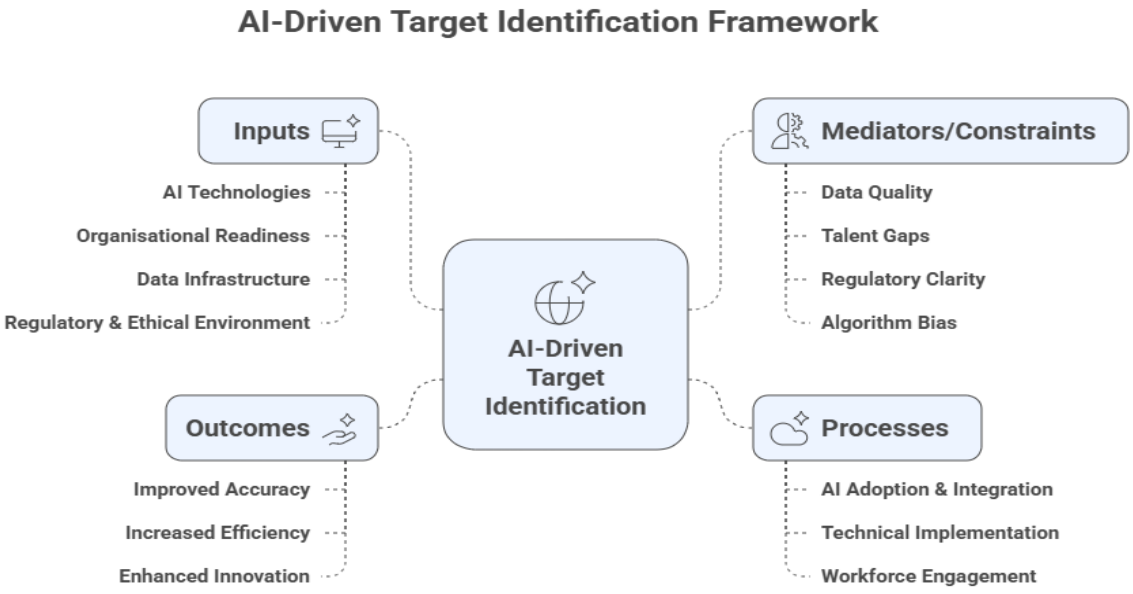

Figure 5. A conceptual diagram designed using Napkin.ai

CHAPTER 3

RESEARCH METHODOLOGY

3. RESEARCH METHODOLOGY

Research methodology is the systematic, logical, and structured approach to analysing a topic. The selection of a suitable conceptual framework, study design, sample plans, data collection instruments, and analytic methods is included. A well-defined methodology ensures that the study is valid, consistent, and capable of producing reliable, impartial, and reproducible results. The research technique utilised to examine how artificial intelligence (AI) might enhance target identification in the biopharmaceutical industry in India. The method provides an organised framework for generating empirical data and contextual insights related to AI's impact on drug discovery processes (Saunders et al, 2019).

Target identification, which involves identifying biological entities such as proteins or genes that can be utilised as therapeutic targets, is a crucial phase in the drug development process (Panda, 2024). Traditional target identification techniques have been costly, time-consuming, and prone to failure. New advances in AI, particularly in machine learning and deep learning, have made it possible to analyse large amounts of biological data to improve the accuracy and efficacy of this process (Mannan *et al.*, 2025). AI has a revolutionary potential to combine these technologies to reduce R&D costs and expedite medication discovery. Assessing the operational, technological, ethical, and regulatory barriers, as well as the extent of AI deployment and its effect on drug discovery success rates, is the goal of this study in the Indian settings (Dhudum *et al.*, 2024).

The research design, participant selection criteria, data collection instruments, ethical precautions, data analysis techniques, and philosophical presumptions are all included in the methodology. While considering the dynamic and intricate character of AI applications in the biological sciences, the methodology aims to answer the main research concerns. This was accomplished by using a mixed-methods approach, which combined quantitative and qualitative methods to guarantee an in-depth understanding of the phenomenon being studied (Dissanayake, 2023).

A systematic quantitative survey and qualitative case studies are both included in the mixed-methods methodology. Online surveys were used to collect quantifiable data from a large sample of professionals employed in the Indian biopharmaceutical sector. This made it easier to spot patterns, attitudes, and connections about the use of AI in drug discovery (Chindhalore *et al.*, 2025). Concurrently, a case study investigation of particular Indian biopharma companies that were aggressively incorporating AI technologies was part of the qualitative

component (Pardeep and Sharma, 2023). This made it possible to examine organisational practices, difficulties, and innovations in greater detail than could be done with numerical data. When combined, these complementary techniques aid in data triangulation and improve the reliability, validity, and comprehensiveness of the study results.

This study is organised according to a set of guiding presumptions and methodological decisions. The Research Onion model by Saunders et al. (2019) is used in this study to ensure a coherent and systematic design (Saunders et al, 2019). It identifies key phases, including research philosophy, approach, strategy, and time horizon. Using a mixed-methods approach, this pragmatic study blends a quantitative survey with qualitative case studies. Google Sheets and theme coding were utilised for analysis, while Google Forms was utilised for data collection. In addition to ensuring that every aspect of the strategy is consistent with the study's objectives, this tiered structure enhances the validity and reliability of the findings.

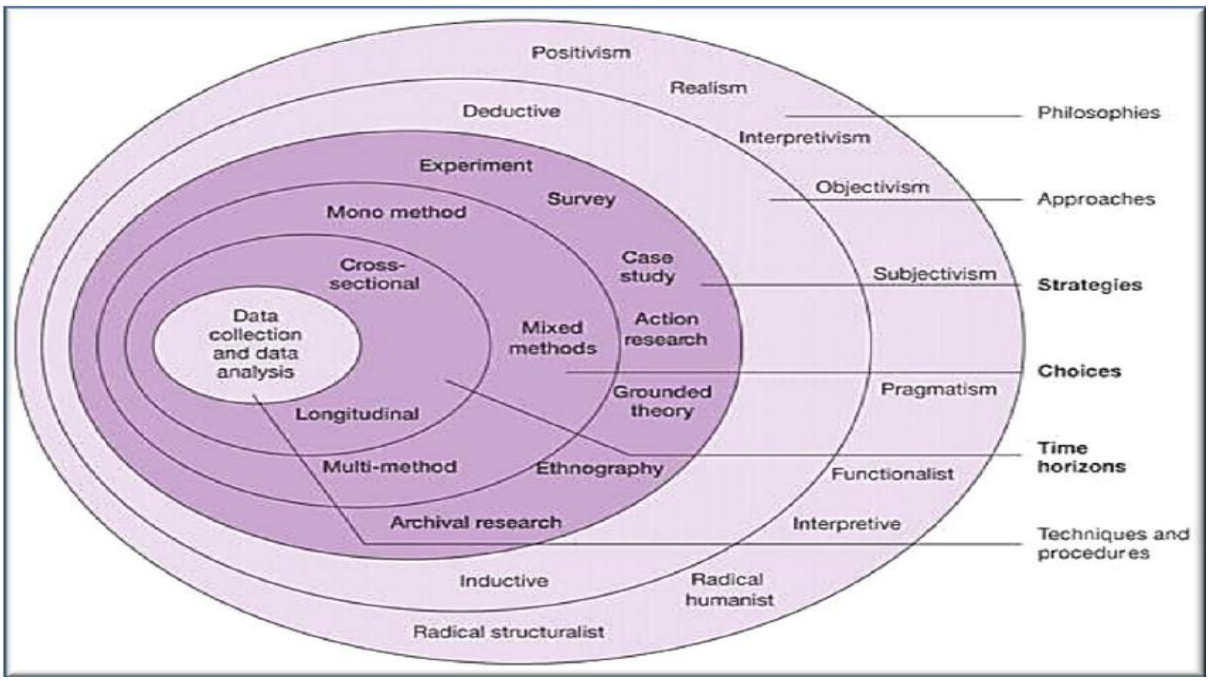

Figure 6. Research Onion: A Systematic Approach for Designing Research Methodology (Saunders et al, 2019)

illustrates a structured research approach that is developed using the layered Research Onion model by Saunders et al. The research philosophy is the outermost layer that shapes the researcher's views. It is followed by the approach (deductive or inductive), the methodological choice (qualitative, quantitative, or mixed), the strategy (e.g., survey, case study), the time horizon (cross-sectional or longitudinal), and the techniques for data collection and analysis. A

crucial choice that ensures coherence and methodological rigor by refining the research design is represented by each layer and is explained clearly in the following headings.

3.1 Research Philosophy

Research philosophy, represented by the outermost layer of the Research Onion, shapes the researcher's perspective and method of knowledge generation. Enumerate the four main streams of thought: pragmatism, interpretivism, realism, and psychology. Positivism, which is based on statistical analysis and empirical observation, holds that reality is quantifiable and objective. While acknowledging the impact of social conditions, realism concurs that there is an objective reality. Interpretivism usually employs qualitative methodologies and is concerned with the subjective meanings people ascribe to experiences (Siddiqui, 2019), (Saunders et al, 2019).

The pragmatic approach used in this study permits methodological adaptability. It makes the case that the research challenge should guide the selection of research methodologies rather than strict adherence to a certain philosophical approach. Pragmatists usually incorporate both quantitative and qualitative methodologies and combine both deductive and inductive reasoning. A mixed-methods methodology is supported by pragmatism in this study, which makes it possible to evaluate organisational practices and contextual challenges through case study analysis and quantitative data collected through standardised questionnaires (Siddiqui, 2019). Examining AI applications in the complex and varied biopharmaceutical industry is best done using this adaptable approach (Allmark and Machaczek, 2018), (Saunders et al, 2019).

3.2 Research Approach

The methodological decision is supported by the logical reasons provided by the research strategy. The deductive method starts with a hypothesis or set of assumptions and then uses empirical facts to test them. It frequently coincides with quantitative research. On the other hand, the inductive method, which is more common in qualitative research, begins with data gathering and aims to generate a theory from observable patterns (Kevin Proudfoot, 2023).

This study adheres to the pragmatic philosophy by combining the two methods. The quantitative component takes a deductive approach, using structured surveys to assess current theories about AI acceptance, efficacy, and difficulties. Simultaneously, the qualitative case study component investigates new insights from AI deployments specific to a company using an inductive approach (Pardeep and Sharma, 2023). Through the triangulation of numerical

patterns with context-based explanations, this blended reasoning improves the findings' depth and reliability (Saunders et al, 2019).

3.3 Research Design

The entire strategy for responding to the research questions is represented in the study design. According to Saunders et al. (2019), (Saunders et al, 2019) the design is defined by three essential elements: the time horizon (cross-sectional or longitudinal), the methodological option (quantitative, qualitative, or mixed), and the purpose (explanatory, descriptive, or exploratory).

The purpose of this study is to thoroughly examine AI adoption patterns, advantages, and constraints in the Indian biopharmaceutical setting using a descriptive and exploratory research design. Using a mixed-methods design, survey data from a variety of professionals, including managers, R&D scientists, data analysts, and other professionals, is combined with qualitative insights from a few chosen case studies of top biopharma companies. The current stage of AI-driven drug development is reflected by the application of a cross-sectional temporal horizon, which records data at a single moment in time (Chindhalore *et al.*, 2025).

3.4 Research Strategy

The research plan outlines the data collection procedure. This study used both primary and secondary sources of information to ensure an accurate assessment.

An online structured survey was used to gather primary data from professionals working in the Indian biopharmaceutical industry. The survey was distributed using Google Forms. Multiple-choice, Likert-scale, and numerical input elements were all included in the questionnaire, which was intended to collect information on participants' experiences with AI, perceived effects on drug discovery, and operational or ethical challenges (Chindhalore *et al.*, 2025). To improve the ease of use, flow, and clarity, a small group pilot test was carried out. Minor changes were made in response to criticism before the complete survey was made public.

The secondary data included case study analysis of publicly available records, corporate reports, and research papers from major biopharma companies like Sun Pharma, Dr. Reddy's, and Biocon. This allowed the researcher to examine the results, challenges, and real-world applications of using AI for target identification. Global regulatory requirements, corporate white papers, and peer-reviewed journal articles all helped to provide context for the findings.

This dual strategy approach enabled triangulation, enhanced the validity of the findings, and provided both interpretative depth and empirical support.

From the drafting of the Research Proposal to the final Dissertation Submission, the Dissertation Timeline is shown in Figure 7, detailing the different stages and their respective deadlines for the research project. To ensure systematic progress tracking and timely completion of all tasks related to the study of AI-Driven Target Identification in India's Biopharmaceutical Industry, the timeline includes specific dates for each task.

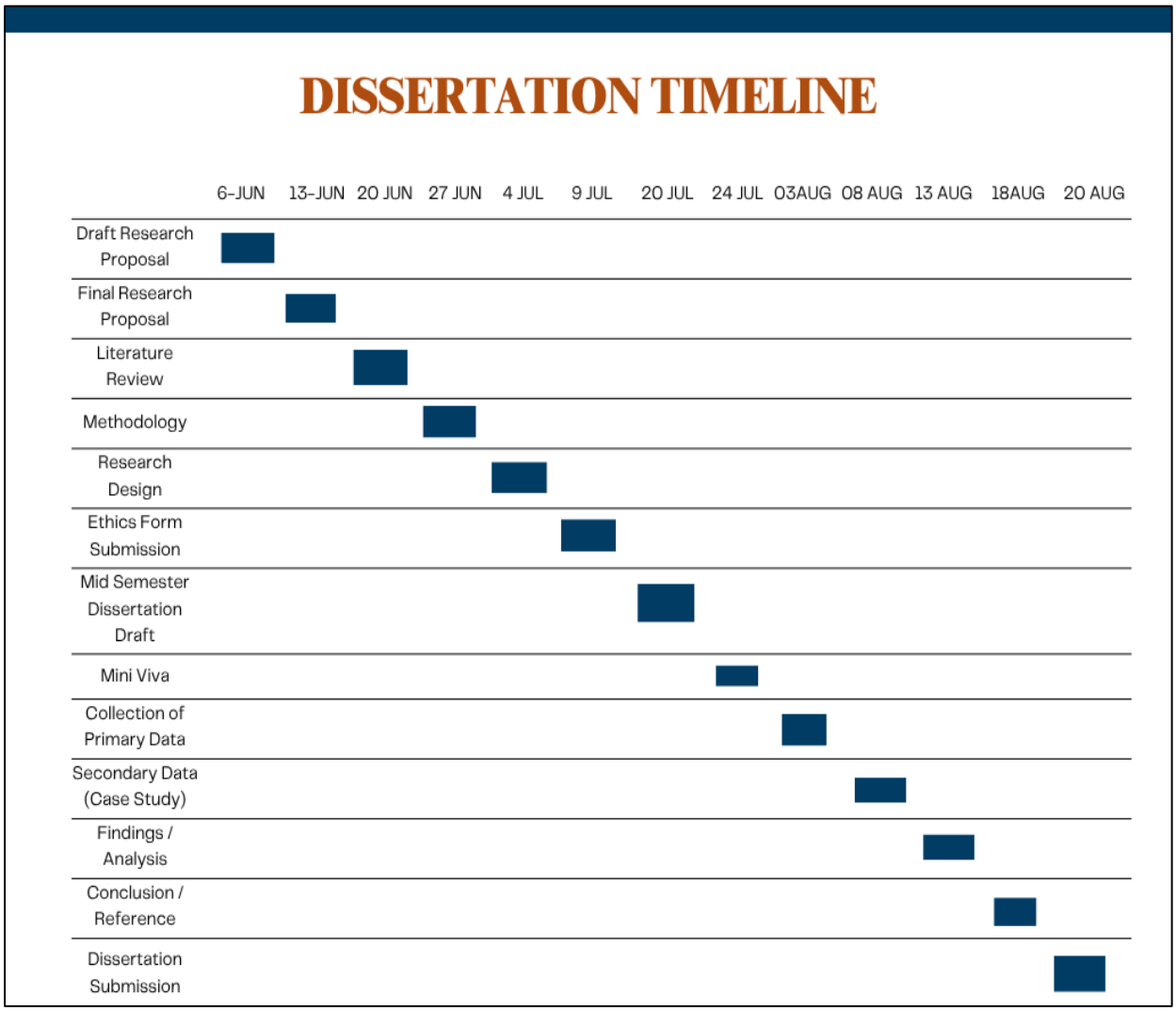

Figure 7. Dissertation Timeline

3.5 Time Horizon

The time horizon refers to the length of data collection. A study can have a cross-sectional (at a single point in time) or longitudinal (over time) design, depending on the Research Onion model.

The cross-sectional temporal horizon was selected due to the nature and extent of this dissertation. Participants' data were gathered during a predetermined period (Saunders et al, 2019). The current perceptions, trends, and challenges related to the application of AI in target identification can be examined in this approach. It is suitable for achieving the study's objectives since it offers a case for evaluating opinions, implementation maturity, and industry competitiveness.

3.6 Ethical Considerations

This study complies with the ethical standards set by Griffith College Dublin and GDPR requirements. Participation was entirely voluntary. Participants were informed about the purpose, how their data would be used, their anonymity, and their rights to withdraw.

No personal information was collected, and all responses were anonymised unless participants explicitly permitted otherwise. A password-protected laptop was used to securely store survey data, and encrypted OneDrive storage provided backups. Only the researcher and supervisor had access. The case study did not involve any confidential internal documents; all information was obtained from open sources. All data will be retained for two years before being permanently deleted. Every effort was made to ensure there was no risk or harm associated with participation.

3.7 Participants and Sampling

3.7.1 Selection Criteria for Participants

Participants were selected through purposive sampling based on their roles in the Indian biopharmaceutical sector, including project managers, regulatory officers, data analysts, R&D scientists, and artificial intelligence specialists. To ensure the relevance and applicability of the results, the eligibility criteria required a minimum of one year of experience in either drug development processes or AI-driven applications in pharmaceutical research. This requirement allowed respondents to offer insightful perspectives on the potential, challenges, and adoption of AI in target identification by ensuring they had both subject expertise and practical experience. The study aimed to include a range of occupations that were both relevant and diverse to capture a comprehensive industry perspective.

3.7.2 Sampling Technique and Size

The study used a non-probability purposive sampling method, followed by snowball sampling through industry forums and professional networks like NASSCOM and LinkedIn. With a 95% confidence level and a ±8% margin of error, the target sample size was 150–200 professionals, which is recommended for survey-based research.

The precise number of AI-related trained professionals working in India's biopharmaceutical sector is not publicly available. However, the pharmaceutical industry in India has approximately 2.7 million direct and indirect employees (Anil Kumar Angrish, 2024), 3,000 pharmaceutical companies, and 10,000+ manufacturing facilities. Biopharma holds the greatest proportion of the biotech market in terms of value (Manasvi Joshi *et al.*, 2024). Finite population effects are insignificant in such a big population, hence n=150–200 (Figure 8) with a 95% confidence level and a ±8% margin of error through the Survey Monkey sample size calculator, and estimated that 151 participants would be needed for reliable results.

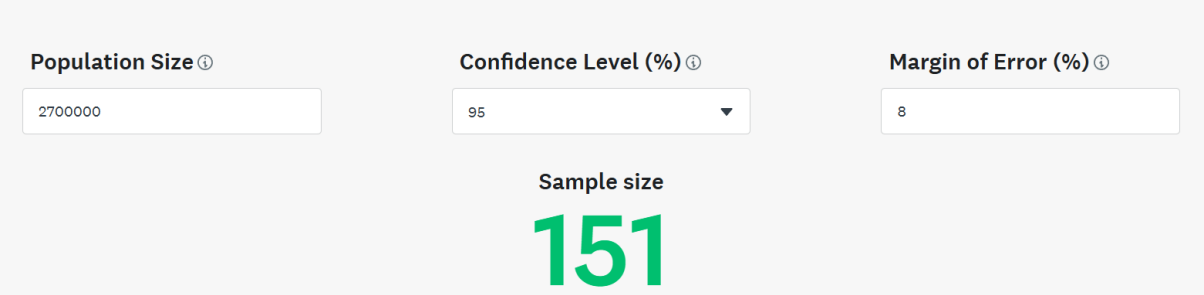

Figure 8. Sample size calculation via Survey Monkey

For the case study component, three well-known Indian biopharmaceutical companies known for their AI initiatives were selected. These were analysed using academic publications, investment reports, whitepapers, and public sources.

3.7.3 Subject Availability and Accessibility

To ensure effective results, I evaluated how accessible each target group was to the Indian biopharmaceutical industry. The goal was to gather responses from a wide range of experts in key roles.

Data Scientists and R&D Professionals: These participants were reached through academic connections and professional networks like LinkedIn, allowing for effective distribution of the online survey.

Industry Managers & Analysts: Many of these professionals, especially those working in AI-driven research areas, may be reached through mutual contacts within the biopharmaceutical industry.

Regulatory and QA Experts: Access to professionals in regulatory affairs was gained through connections made by academic peers and professional associations, offering valuable insights into compliance issues related to AI.

Case Study: Organisations were selected based on information gathered from industry publications, academic journals, and white papers demonstrating that Indian biopharma companies were actively using AI-driven target identification technology.

3.8 Data Analysis

Quantitative methods were used on the survey data to identify trends, patterns, and correlations. Data analysis and visualisation were performed using Microsoft Excel (Microsoft 365, Version 2407). The following steps were taken:

3.8.1 Data Cleaning

Responses that were incorrect or inconsistent were removed during the cleaning process. Microsoft Excel was used to clean the survey data collected from professionals in the Indian biopharmaceutical sector.

Every response was reviewed by hand to ensure that no information was missing, incorrect, or duplicated. Basic Excel functions like filtering, sorting, and conditional formatting were applied to identify mistakes or missing data.

Most of the cleaning was done by hand to ensure data reliability and accuracy. By doing this, the dataset's integrity was guaranteed before analysis.

3.8.2 Descriptive Statistics

Descriptive statistics, including frequencies, percentages, averages, and standard deviations, were used to summarise the participants' demographic information as well as their responses regarding AI adoption, perceived benefits, and organisational challenges. Pie charts, bar charts, and other visual aids were employed to better illustrate these results, emphasising important patterns and trends in the survey data.

3.8.3 Inferential Statistics

To investigate correlations, a Chi-Square test was applied to assess the relationship between professional roles and AI adoption levels, appropriate for categorical survey data analysis.

3.8.4 Data Visualisation

To illustrate patterns and distributions, visual aids such as pie charts, bar charts, and columns were used. The percentage of specialists who agreed that AI enhances target recognition accuracy was presented in charts.

3.8.5 Research Process Overview

The study's findings are critically analysed within the context of its stated objectives and the wider scholarly literature on AI applications in drug discovery. This research offers a comprehensive understanding of how extensively AI-driven target identification technologies are employed across different organisational types and professional roles in India's biopharmaceutical industry. The analysis highlights key enabling factors, operational and technological challenges, and stakeholder perceptions that influence adoption trends. These insights are crucial for developing regulatory frameworks that support the industry's digital transformation, foster innovation, and guide future efforts to incorporate AI.

The research methodology for this study on AI-driven target identification in India's biopharmaceutical industry is organised and depicted in a flow chart (Figure 9) as follows: development of the survey and purposive selection of case study firms; online distribution and collection of both quantitative and qualitative data; thematic analysis of case studies and descriptive analysis of survey responses; systematic data cleaning and integration of both datasets using a mixed-methods approach. This well-organised technique enables the generation of insightful results that directly support the study's goals, and it also guides the final discussion and strategic recommendations.

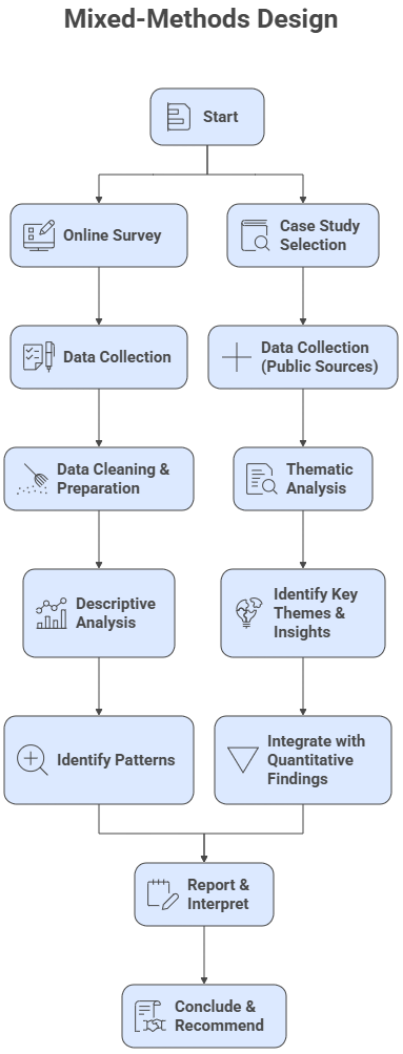

Figure 9. Flow Chart: Research Methodology & Data Analysis created by Napkin.ai

CHAPTER 4

FINDINGS AND ANALYSIS

4. FINDINGS AND ANALYSIS

This chapter compiles survey results from 151 professionals in India's biopharmaceutical industry and case studies of three companies, focusing on AI-driven target identification in drug discovery. Using descriptive analysis, it examines how AI influences decision-making, accuracy, and efficiency. The chapter also analyses operational and technological challenges, ethical and legal issues, and potential future developments. Incorporating both quantitative and qualitative data, it provides a comprehensive overview of AI adoption and strategic use in India's biopharma sector.

4.1 Descriptive Analysis

To summarise survey results, descriptive analysis is conducted using pie charts, bar charts, and column charts. These graphics highlight the levels of AI adoption, significant obstacles, and responses from participants across various professional categories. Clear examples illustrate patterns such as the occupations that use AI the most, the therapeutic areas prioritised, and obstacles like infrastructure or cost. This analysis provides a comprehensive overview of current practices in India's biopharmaceutical industry by combining these graphical insights with existing literature.

Section 1&2: Participant Demographics: Roles and Experience

The survey was completed by 151 professionals from various fields within India's biopharmaceutical sector. The graphic representation of a pie chart (Figure 10) shows how professionals are distributed across roles, emphasising the interdisciplinary nature of AI adoption and revealing that managers (17.3%), data analysts (18.0%), and scientists (19.3%) are the three largest groups. Smaller but equally significant numbers included regulatory affairs specialists, pharmacologists, artificial intelligence researchers, medicinal chemists, and clinical research associates. This distribution underscores the multidisciplinary nature of AI-driven innovation, illustrating that AI applications in drug development involve technical, analytical, and managerial activities beyond just research scientists.

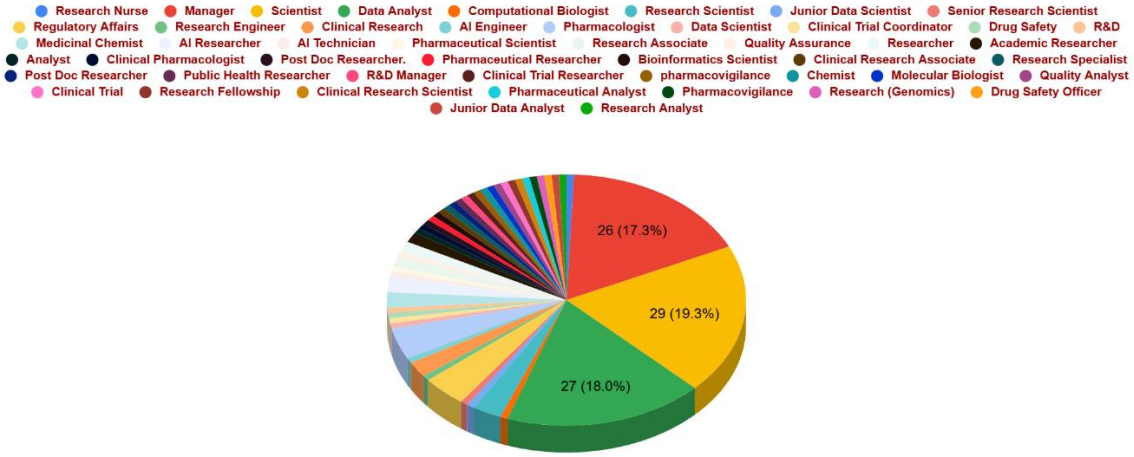

Figure 10. Distribution of Participants' roles in India's biopharmaceutical Sector

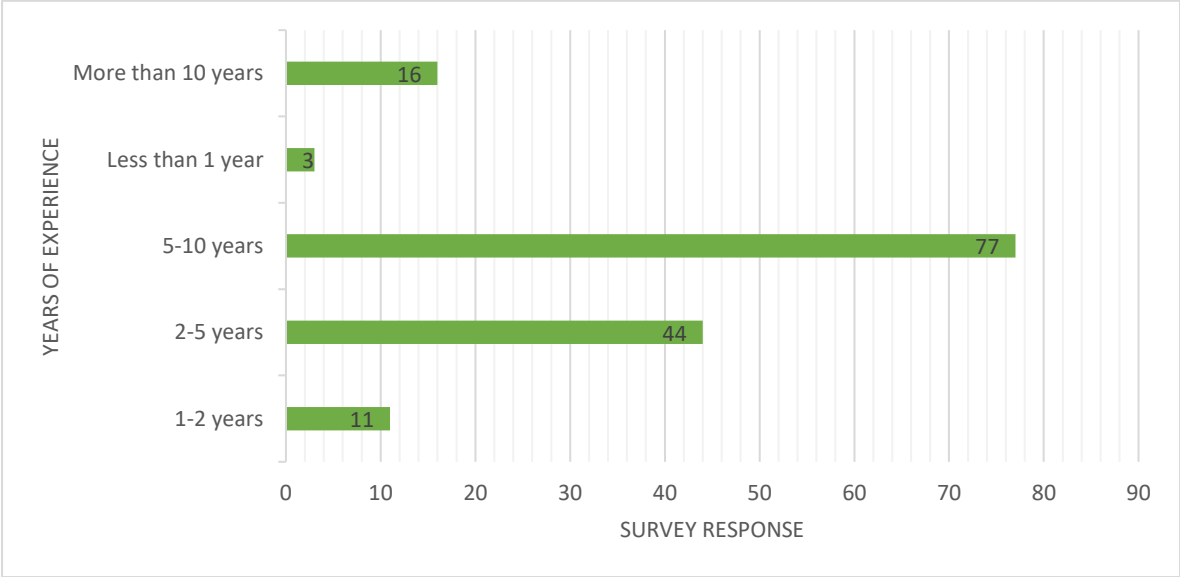

Figure 11. Distribution of Participants by Years of Experience

The column chart in Figure 11 displays experience levels, with most respondents (51%) having worked for five to ten years. This is followed by those with two to five years (29.1%) and over ten years (10.6%). Respondents with less than a year and one to two years of experience combined make up 13% of the sample. Mid-career professionals appear to be the primary contributors to AI applications, as they can balance subject expertise with adaptability to new digital technologies.

These findings align with earlier studies that emphasise the importance of diverse stakeholder interaction for effectively using AI technologies. They clarify how AI adoption differs across various professional roles and career stages by demonstrating how organisational dynamics, experience, and role-specific tasks influence technology integration. This enhances the understanding of the factors that impact AI use in India's biopharmaceutical sector.

Section 3: AI Tools Used for Drug Discovery

According to the survey's findings, Indian biopharmaceutical companies use various AI technologies for drug discovery. Figure 12 shows that machine learning and deep learning are the most common, followed by generative AI and natural language processing. The limited use of quantum computing indicates early-stage exploration. These patterns match research indicating that NLP assists with literature mining and data integration, while ML and DL improve predictive modelling for target identification. The distribution of AI tools reflects a practical approach to AI adoption, with companies selectively implementing technologies that provide immediate operational and strategic benefits.

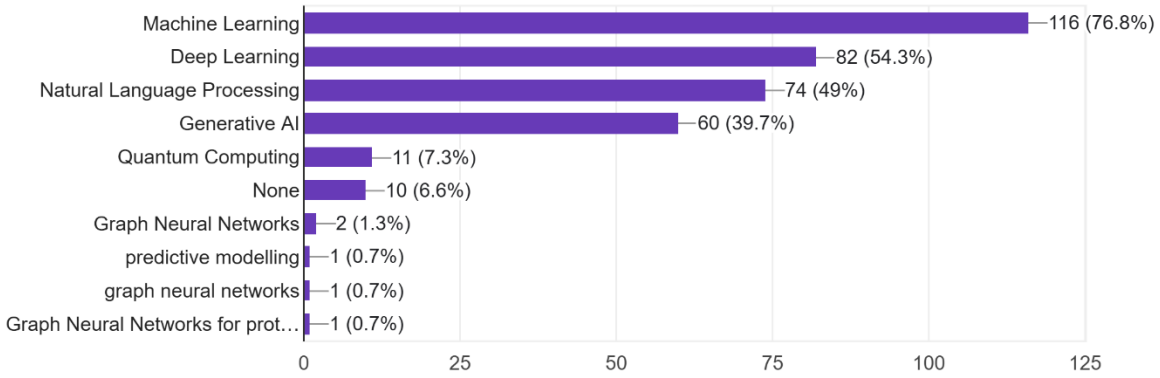

Figure 12. AI Tools used in Drug Discovery

Section 4: Extent of AI Integration

According to survey results, Figure 13 shows that Indian biopharmaceutical companies have varying levels of AI integration; most are at the pilot or partial stages, while a small number have fully integrated AI. Fewer people remain unsure or have not used AI at all. This pattern aligns with the literature on gradual adoption in the biopharmaceutical industry, which shows that widespread deployment follows initial trials. The results indicate that although AI usage is

rising, organisations still face challenges like data readiness, infrastructure, and skills. Partial adoption suggests that R&D processes are being improved rather than fully transformed.

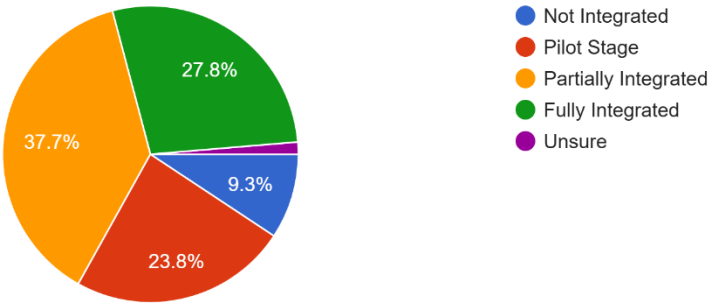

Figure 13. Levels of AI Adoption Across Indian Biopharmaceutical Organisations

Role	Pilot Adoption	Full Adoption	No Adoption
Manager	25	7	1
Analyst	22	4	3
Scientist	20	5	2

Table 1. Cross-tabulation of Professional Role and Level of AI Adoption

The cross-tabulation in Table 1 shows that pilot-stage adoption is mainly managed by managers (25) and analysts (22), with scientists (20) also making a significant contribution. All groups continue to have relatively low rates of full adoption, although managers (7) report slightly higher percentages. The low rate of non-adoption indicates that, even if cautiously, AI adoption is growing across different professional roles.

Section 5: Therapeutic Areas

The most common use of AI across therapeutic areas, according to survey results in Figure 14, highlights oncology as the leading focus, with increasing applications in infectious diseases, diabetes, cardiovascular conditions, and neurological disorders. Due to its complexity and unmet clinical needs, oncology remains a global priority in AI-driven research, as demonstrated by its importance. Although less common, other therapeutic applications show that AI is being more broadly used to treat high-burden illnesses in India. Adoption levels varied, as indicated by the small percentage reporting no application. These findings align with research showing

that oncology was the first therapeutic area to adopt AI, with other disease areas gaining attention over time.

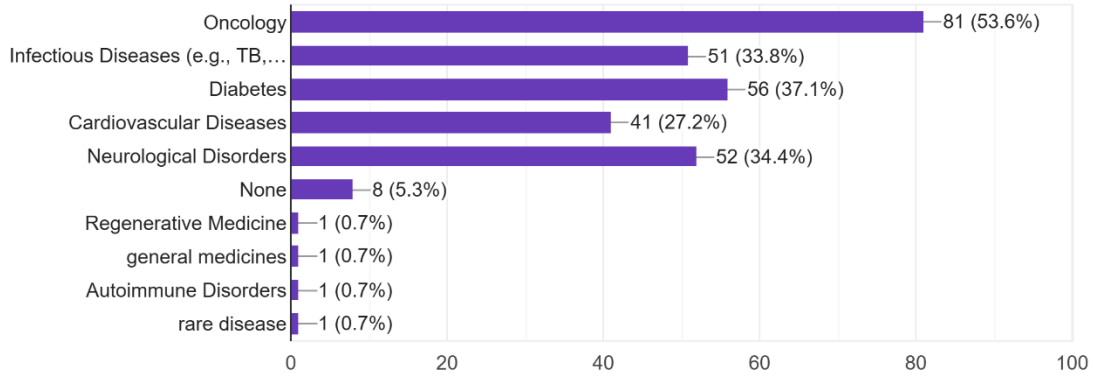

Figure 14. AI Applications by Therapeutic Area

Section 6: External AI Collaborations

Figure 15 shows that most Indian biopharmaceutical companies depend on commercial AI systems like Benevolent AI and Insilico Medicine; some also partner with Atomwise, Deep Genomics, Exscientia, Medidata AI, and Recursion. While some develop their own AI systems or form joint ventures, academic collaborations are uncommon; IIT/IISc partnerships are mentioned only once. To improve early-stage target prediction, molecular generation, and focused drug development, this pattern indicates that external AI collaborations mainly provide specialised computational skills, datasets, and predictive modelling tools to boost AI's role in drug discovery.

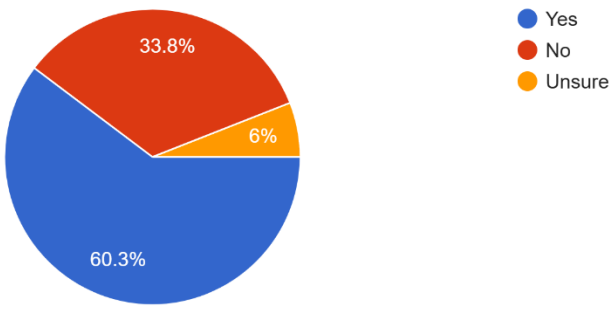

Figure 15. External and Internal AI Systems in Indian Biopharmaceutical Companies

The survey data on how often companies work with outside AI platforms for target identification in drug research is shown in Figure 16's horizontal bar chart. Insilico Medicine

and Benevolent AI received 26 and 24 responses, respectively. It demonstrates how the industry is moving toward integrating AI, which will enhance the accuracy and efficiency of drug discovery.

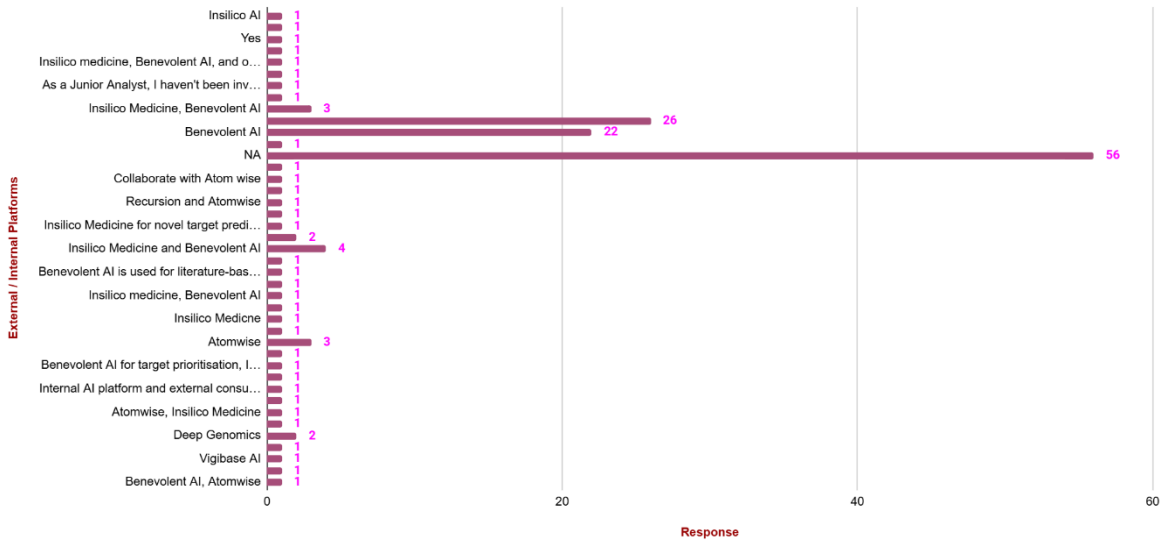

Figure 16. Frequency of Collaboration with External AI Platforms in India's Biopharmaceutical Industry

Section 7: Primary Motivation for AI Adoption

The survey results shown in Figure 17 indicate that improving time efficiency and accuracy in target identification are the main reasons why Indian biopharmaceutical companies adopt AI. Although regulatory compliance is not heavily stressed, gaining a competitive advantage and cutting costs are also important factors. Globally, the industry recognises AI for enhancing predictive reliability and speeding up drug development, which aligns with these objectives. The emphasis on accuracy and efficiency underscores AI's strategic role in overcoming traditional R&D challenges, while financial and competitive benefits further encourage adoption.

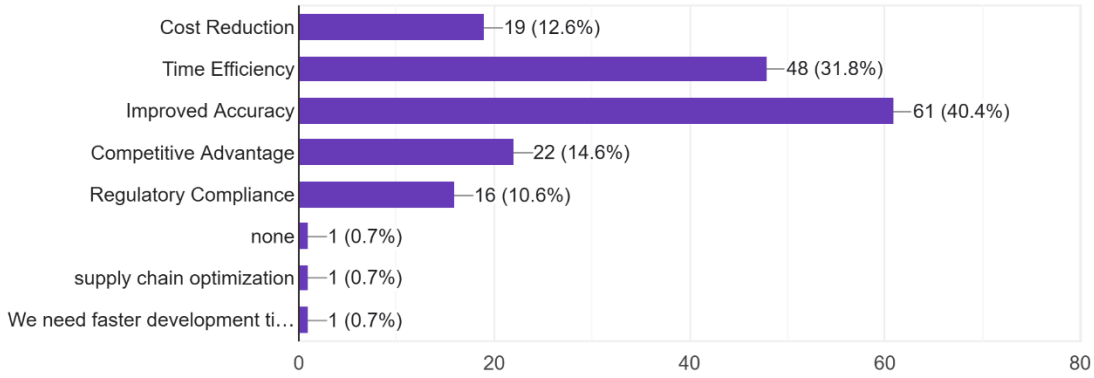

Figure 17. Key Drivers for AI Adoption in Indian Biopharmaceutical Companies

Section 8: Extent of Improvement in Accuracy

According to survey responses, the pie chart in Figure 18 shows that Indian biopharmaceutical companies rated AI's impact on accuracy as 4 (35.8%) on the scale, indicating a moderate improvement, and neutral (25.8%). While a few reported little to no change, a smaller group noted significant improvements (24.5%). The justifications included fewer inaccurate results, better molecular matching, and enhanced predictive modelling. Several participants acknowledged that results still depend on model training and data quality. Although AI's effectiveness is still evolving across companies, the overall findings suggest it provides substantial accuracy improvements.

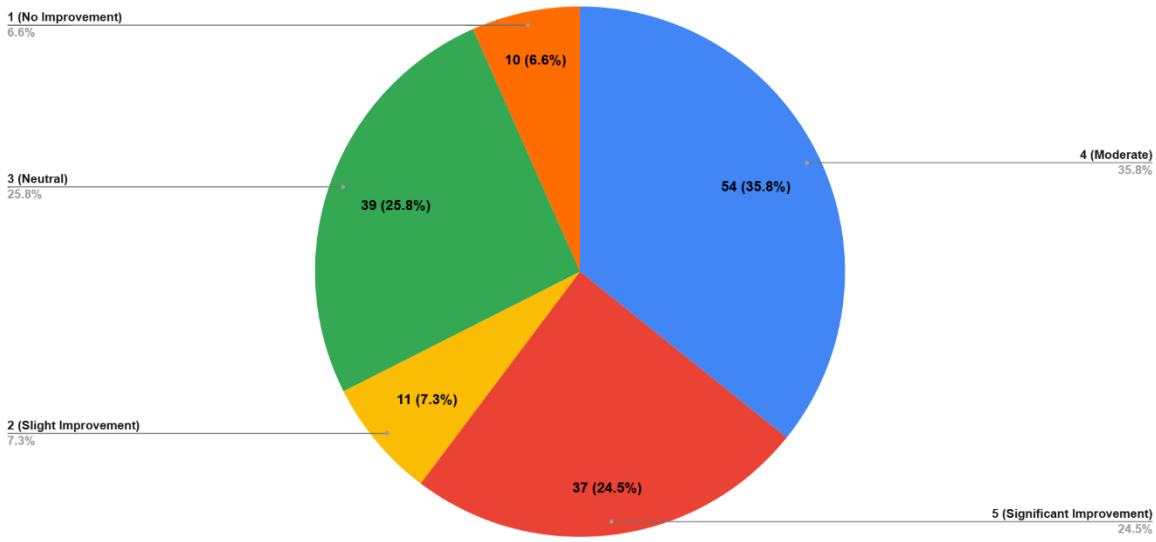

Figure 18. Perceived Improvement in Target Identification Accuracy Due to AI

A wide range of industrial experiences is depicted in Figure 19 (a pie chart), which illustrates various AI outcomes in target identification. It shows that 2% report no impact, while others see benefits such as increased accuracy (1%), improved efficiency (1%), and the discovery of new biomarkers (1%). The survey responses explain the perceived improvements in target identification accuracy due to AI.

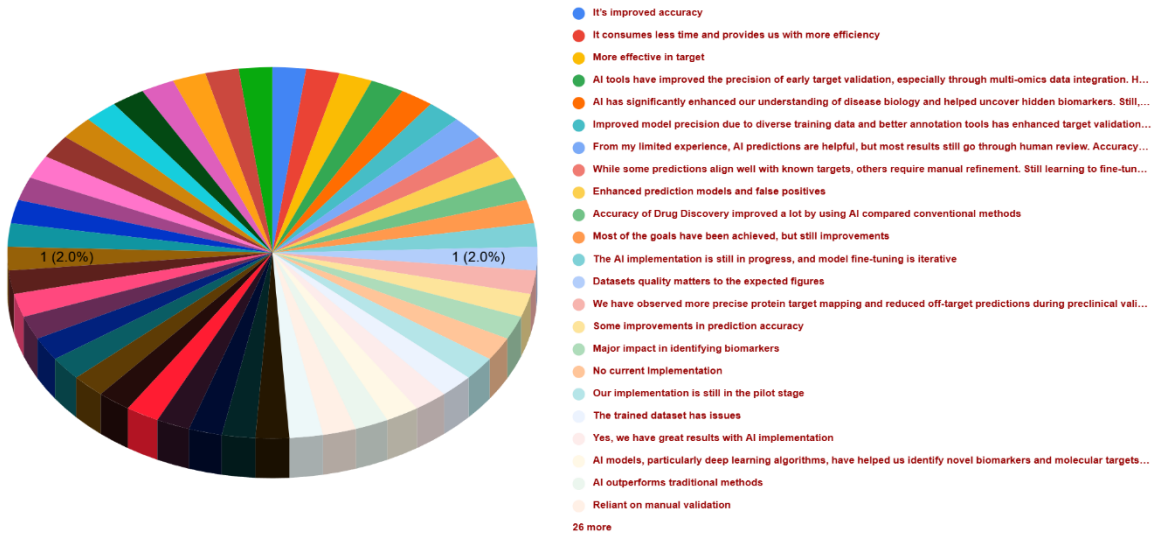

Figure 19. Perceived Outcomes of AI Implementation in Target Identification

Respondents stated that AI's capacity to detect patterns in big datasets, lower human error, and aid in predictive modelling contributed to increased accuracy. Nonetheless, some pointed out

that advantages were still limited in cases where data quality was uneven or AI models were still being integrated into research workflows.

Section 9: Reduction in Target Identification Time

According to survey results, the pie chart in Figure 20 shows that most participants reported an 11–20% or 21–30% reduction in target identification time, demonstrating how effective AI is at accelerating the early stages of drug discovery. Several participants also noted a decrease of over 30%, emphasising a revolutionary impact. Some respondents reported little to no reduction, often citing inadequate AI integration or a lack of high-quality datasets. These findings suggest that while AI speeds up timelines, the level of benefit varies depending on the current state of infrastructure, data readiness, and how widely AI has been adopted by different organisations.

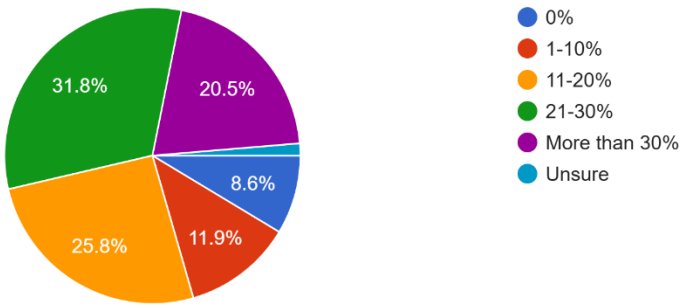

Figure 20. Percentage Decrease in Target Identification Duration Attributed to AI

Automated repetitive screening processes, accelerated data processing, and reduced unnecessary testing through predictive approaches. Businesses with better infrastructure and high-quality datasets were more efficient than those struggling with system integration and data preparation; however, the level of decline varied.

The bar graph in Figure 21 illustrates the many advantages and difficulties of adopting AI. The majority of answers highlight efficiency, automation, and early prediction. Some point to restrictions, including lack of use, restricted data, and restricted implementation. Early prediction has the highest frequency (6.1%), suggesting that it is highly relevant to present practices.

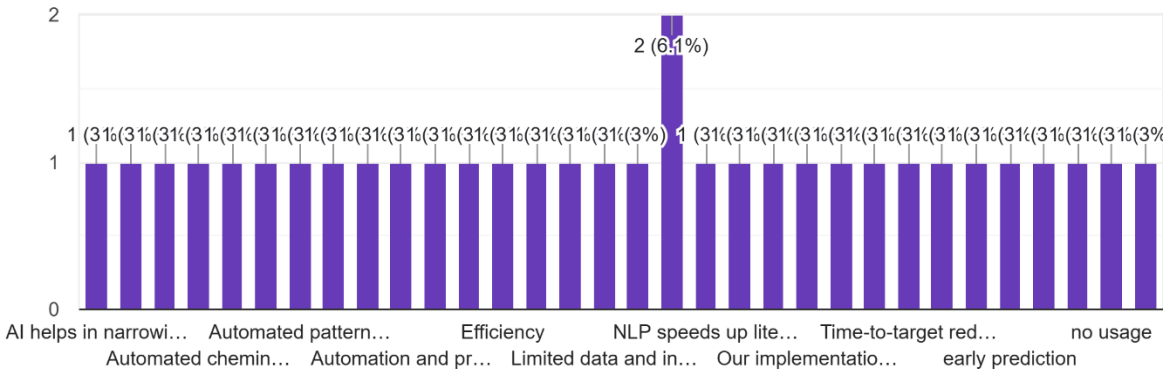

Figure 21. Reasons for the Reduction in Target Identification Time of AI Adoption

Section 10: Percentage Reduction in R&D Costs

According to survey results, Figure 22 shows the responses in a pie chart, indicating that time savings from using AI often surpass the modest cost reductions (1-20%). Fewer than 30% of Indian biopharmaceutical companies reported actual cost savings, with most experiencing time reductions of 1–10% or 11–20%. Some participants reported no significant decreases, often due to high recurring costs for infrastructure, data quality, and professional expertise. The data suggests that AI provides incremental cost benefits in R&D overall, with additional savings likely as adoption matures and supporting systems improve.

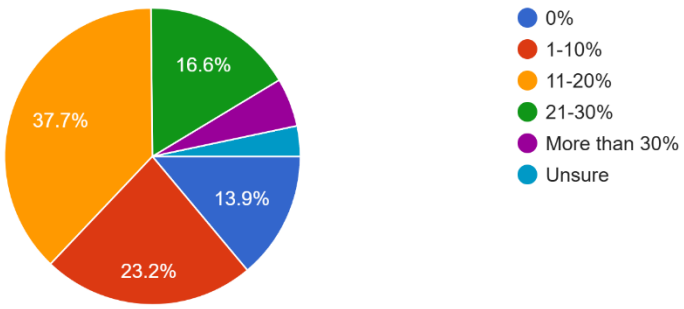

Figure 22. Cost Reduction from AI Adoption in Biopharmaceutical R&D

Artificial intelligence's ability to optimise processes, eliminate repetitive experiments, and provide more precise target selection has been a major factor in reducing costs. However, some organisations noted that initial savings are often offset by infrastructure investments and knowledge development, leading to mixed results regarding AI's overall financial benefits.

The bar graph in Figure 23 shows the reasons behind the percentage reduction in R&D costs and the various effects of using AI tools in biopharmaceutical research and development. Most responses indicate modest gains in efficiency and a reduction in manual work. However, reductions in wet-lab effort and cost savings are less common. Uneven adoption results are evident, as some companies report little benefit due to monitoring issues or high operating costs.

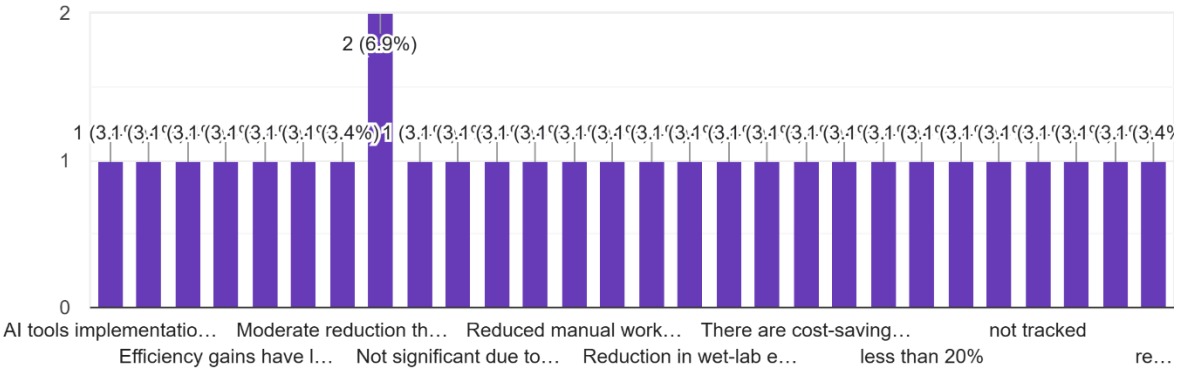

Figure 23. AI Adoption Effects

Section 11: Specific Outcomes from AI use in Target Identification

According to the survey results, using AI for target identification offers several clear benefits. The bar chart in Figure 24 shows that the most common advantages include discovering new targets (49%), accelerating drug development timelines (55.6%), and reducing R&D (29.8%) costs. Some respondents also mentioned improved patient outcomes, highlighting the translational potential of AI-driven strategies. The fact that few people reported no noticeable benefits indicates that AI is already beginning to make a measurable impact on research workflows. These findings support AI's expanding role as a valuable driver of innovation in drug discovery despite mixed cost implications.

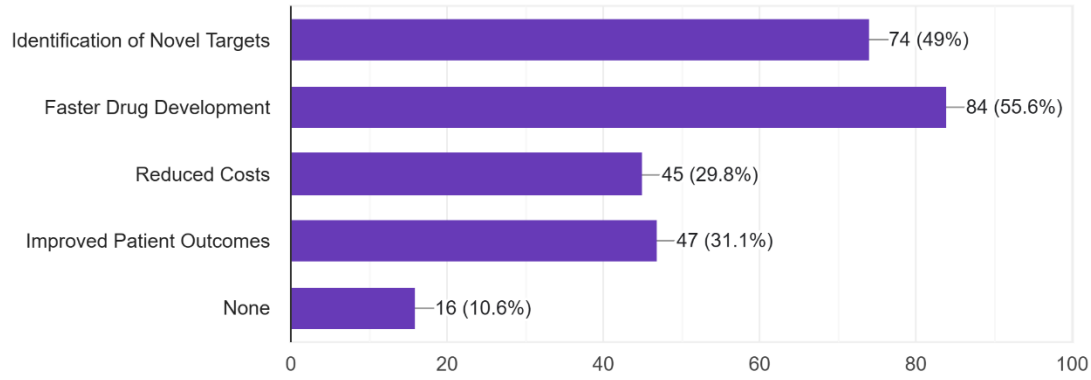

Figure 24. Benefits of AI in Biopharmaceutical R&D

Section 12: Primary Challenges in Implementing AI for Target Identification

Respondents identified several obstacles as barriers to successful AI use in target identification. The pie chart in Figure 25 highlights the most common concerns, including data quality issues such as inconsistent or fragmented datasets and a lack of AI expertise within organisations. Other frequently cited obstacles include high implementation costs, algorithm bias, and inadequate infrastructure for high-performance computing. Only a small percentage of participants mentioned regulatory uncertainty as a barrier. These findings suggest that, although technological and operational challenges are predominant, regulatory issues still raise concerns, emphasising the complex barriers to wider AI adoption.

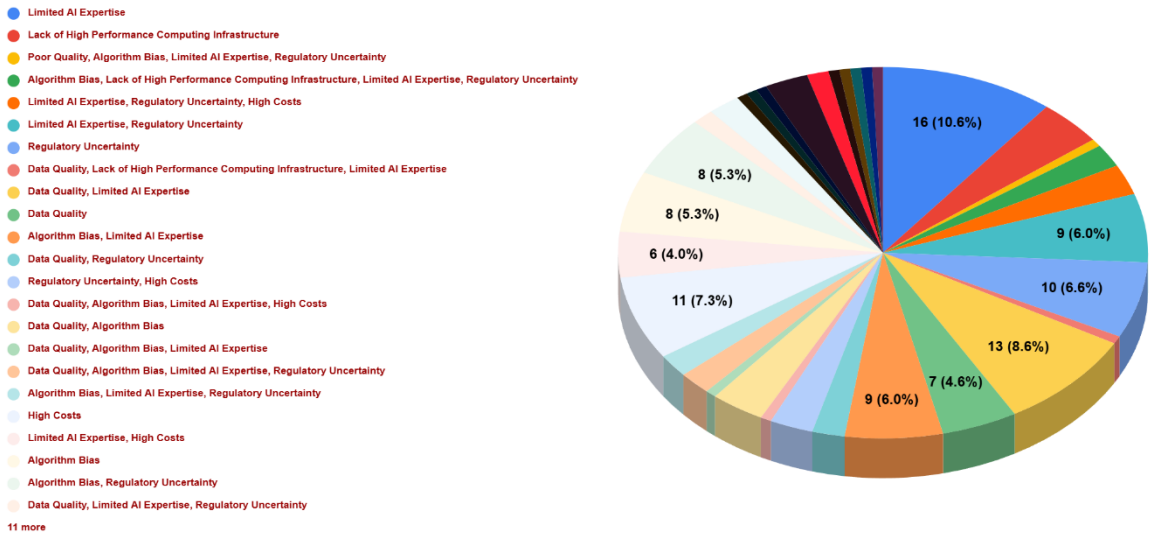

Figure 25. Key Barriers to AI Adoption

Concerns about algorithm bias, limited access to high-performance computers, and lack of experience were among the challenges mentioned by the respondents. Implementation costs and regulatory uncertainties were also highlighted, illustrating the complex interactions between organisational, technological, and governance factors that influence how effectively AI can be integrated into target identification processes.

The adoption of AI by Indian biopharmaceutical companies faces challenges such as lack of experience, poor data quality, algorithm bias, unclear regulations, and high costs. Since these issues often overlap, they create complex obstacles that hinder progress. The pie chart in Figure 26 shows that investments in infrastructure, clearer regulations, and targeted skill development across the industry are all necessary, as highlighted in the survey responses.

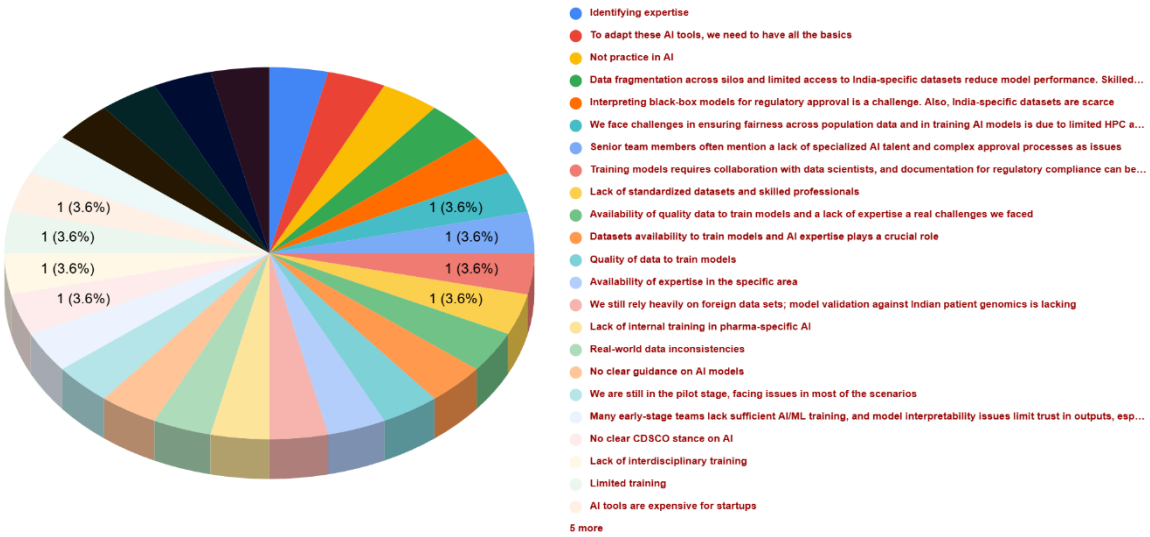

Figure 26. Reasons for AI Adoption Barriers in Biopharma

Section 13: Most Significant Barrier to AI Adoption

According to survey results, the pie chart in Figure 27 shows that the biggest obstacle to AI adoption is a lack of experience (35.1%), closely followed by concerns about infrastructure and data quality. Other respondents cited a lack of funding and regulatory gaps as major obstacles. These findings suggest that technological readiness and human capital are crucial for successful AI deployment; however, organisational and regulatory support also influence adoption. To enable broader use of AI-driven target identification in the biopharmaceutical industry, these challenges must be addressed.

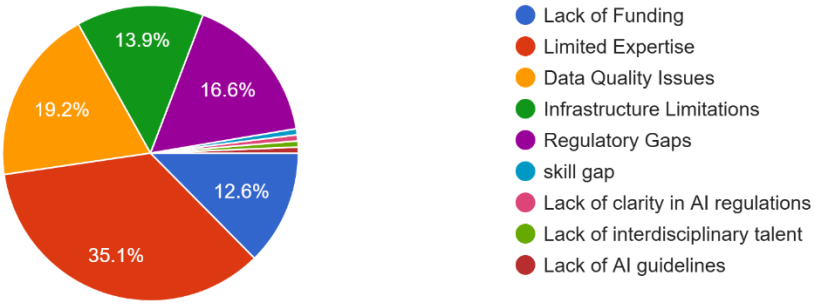

Figure 27. Top Challenges in Biopharma AI

The main obstacles included concerns about data quality, financial constraints, and limited access to qualified professionals. Additionally, respondents pointed out the lack of infrastructure and regulatory gaps, which together slow down the scalability of AI adoption and delay its effective use in tackling the industry's complex drug discovery challenges.

Each of the challenges in AI-driven drug discovery listed in Figure 28 was mentioned by 3.2% of respondents. Major issues include fragmented data, a lack of cross-trained personnel, limited exposure to AI, and insufficient funding. Many companies struggle to incorporate physiological aspects into machine learning frameworks due to a lack of transdisciplinary knowledge.

Figure 28. Reasons for the Top Challenges in Biopharma AI

Section 14: Primary Source of Data Quality Issues

Respondents identified several causes of data quality issues in AI-driven target identification. The bar chart in Figure 29 shows that the most common challenges included inconsistent data collection (33.1%), fragmented datasets (27.2%), and the lack of datasets specific to India (38.4%). Fewer participants reported no major concerns about data quality. These findings highlight that standardised, comprehensive, and locally relevant data are crucial for the effectiveness of AI platforms, emphasising the need for better data management techniques to improve operational efficiency and predictive accuracy in drug discovery.

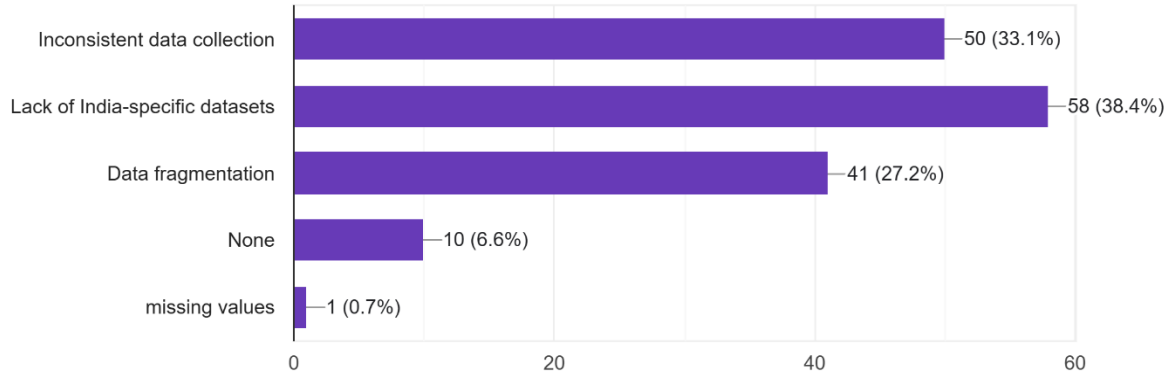

Figure 29. Data Quality Issues in Indian Biopharma for AI

Section 15: Infrastructure Limitations

Participants in the survey identified several infrastructure limitations that hinder the use of AI for target identification. The bar chart in Figure 30 shows that the most common issues are limited high-performance computing capacity, affecting about 40% of respondents, poor internet connectivity, and insufficient cloud storage. Most respondents emphasised that these limitations significantly hinder the adoption of advanced AI models and large-scale data processing, although a small percentage of companies reported no major infrastructure problems. These findings suggest that improving digital infrastructure is a crucial step toward enabling wider use of AI technology in India's biopharmaceutical industry.

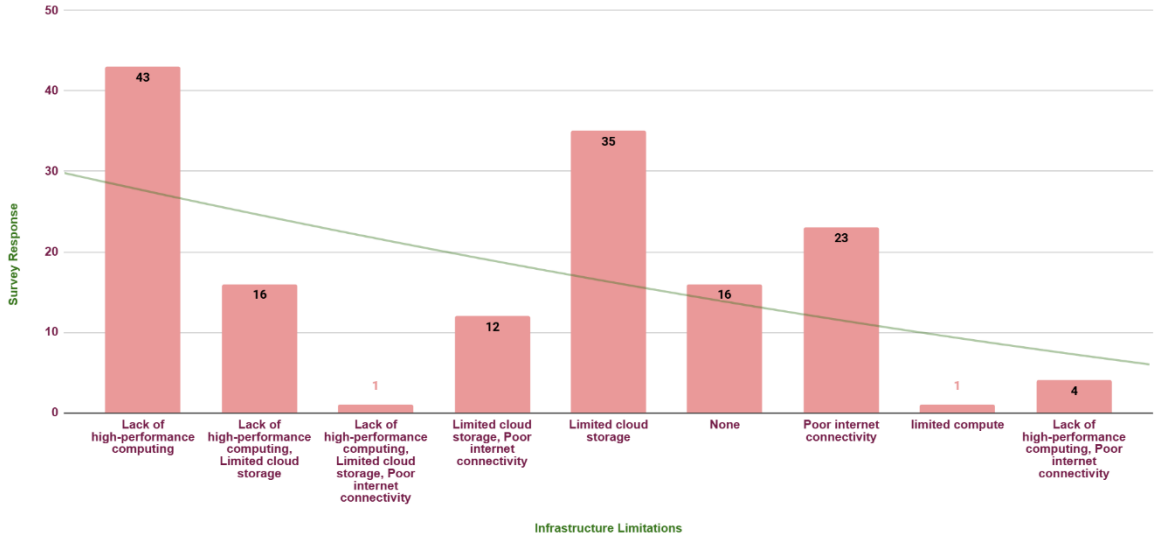

Figure 30. Key Infrastructure Constraints in Biopharma

Section 16: Measures to Address Algorithm Bias

In Figure 31, the bar chart shows that survey responses reveal various strategies for addressing algorithm bias in AI-driven drug discovery. While some companies focus on training models with diverse datasets and regularly auditing AI systems, a notable number of organisations (34) report not taking any proactive measures. Others emphasise collaboration with external experts to ensure models' robustness and fairness. These findings hinder reliable AI use in target identification, indicating that although awareness of algorithmic bias is increasing, systematic and standardised mitigation methods remain limited.

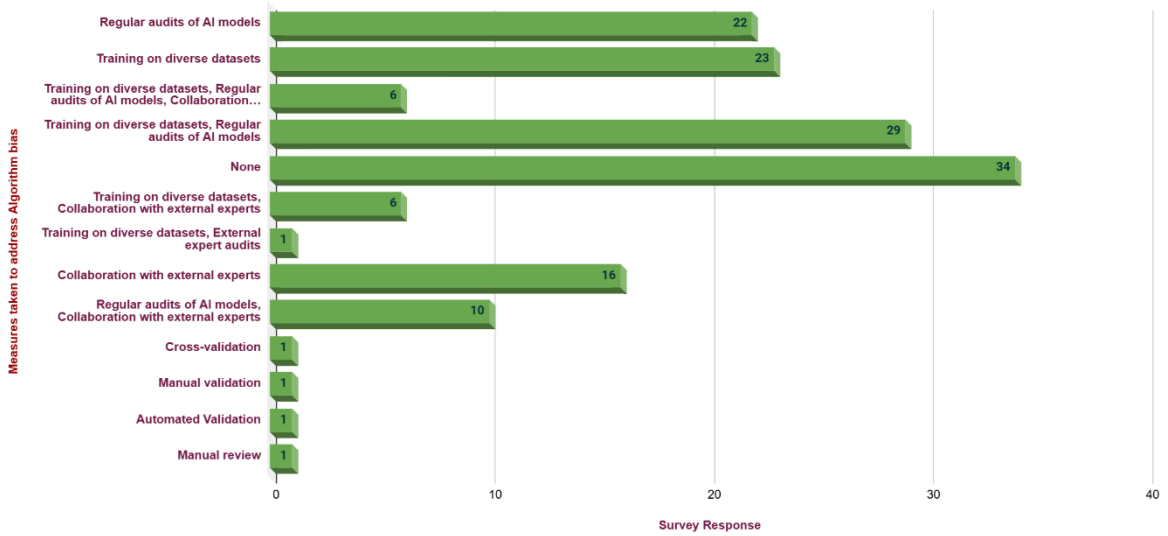

Figure 31. Strategies for Addressing Algorithm Bias

Section 17: Likelihood of Adopting Advanced AI Technologies in the Next 5 Years

In Figure 32, the pie chart shows that respondents have expressed diverse expectations regarding the adoption of advanced AI technologies such as quantum computing and generative AI. Reflecting optimism about these technologies' potential to transform target identification, many respondents indicated they are likely or very likely to implement them within the next five years. Some mentioned uncertainty about cost-effectiveness and technical maturity, remaining neutral or unlikely. Based on these responses, companies should take a cautious yet forward-looking approach that balances enthusiasm for innovation with awareness of implementation challenges and resource limitations.

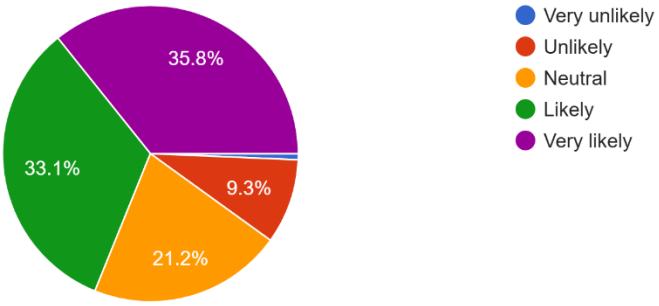

Figure 32. Future Adoption of Advanced AI

Competitive challenges, worldwide innovation trends, and AI's potential to revolutionise discovery procedures were highlighted by optimistic respondents as adoption drivers. More skeptical participants, on the other hand, pointed to prohibitive costs, infrastructure constraints, and technical complexity as obstacles, underscoring the disconnect between idealistic viewpoints and the actual implementation realities.

In Figure 33, the pie chart shows, companies are utilising generative AI for molecular design for a number of reasons. From strategy alignment and infrastructure readiness to innovation and legal clarity, each component is equally significant. The even distribution points to a broad, exploratory stage in which businesses test their potential while negotiating internal obstacles and external market movements.

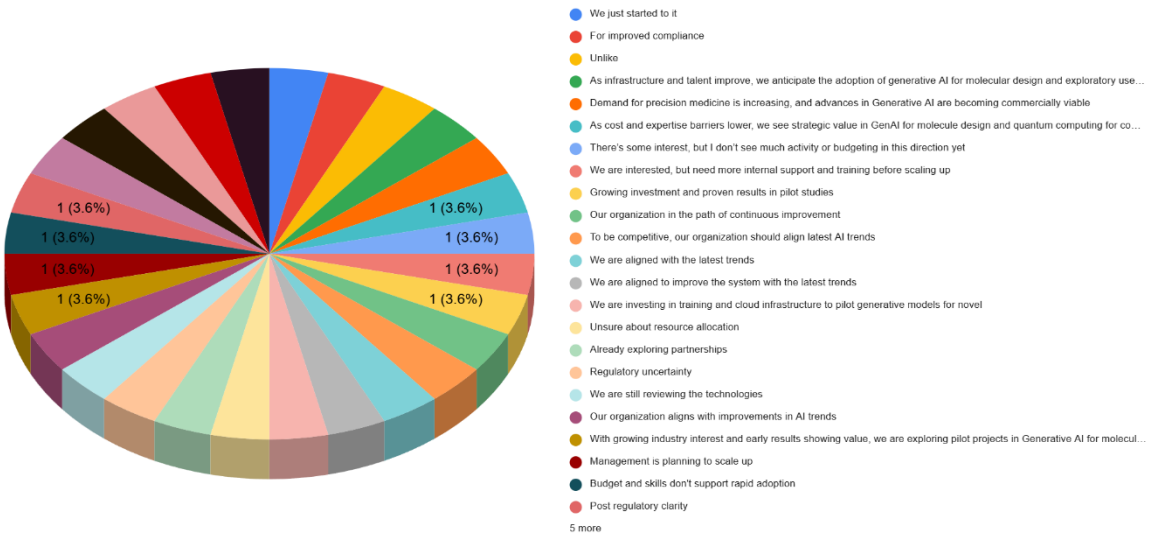

Figure 33. Reasons for the Adoption of Advanced AI

Section 18: Most Promising Advanced AI Technology

According to survey responses, the pie chart in Figure 34 shows that generative artificial intelligence (AI) is viewed as the most promising technology (53%) for advancing drug discovery, especially in molecular design and new target prediction, highlighting its growing influence in innovation and application. Due to high costs and current technical immaturity, quantum computing (15.2%) is also acknowledged, mainly as a long-term possibility. Fewer participants believe that complex biological datasets can be managed by Graph Neural Networks (GNNs) (19.2%). Others (10.6%) had no response, and only 0.7% mentioned Natural Language Processing, indicating a lack of awareness or willingness to adopt. Overall, the responses suggest that generative AI is now regarded as the most important technology in the near term. The chart reflects a strong industry focus on generative models, likely due to their versatility in drug design, data synthesis, and predictive analytics.

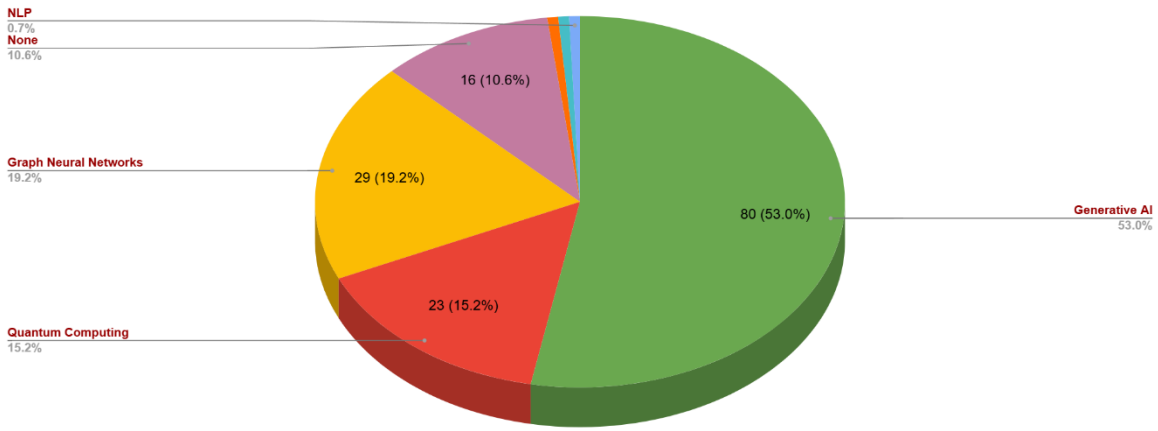

Figure 34. Promising AI Technologies in Drug Discovery

Section 19: Perceptions of Quantum Computing in Target Identification

In Figure 35, the pie chart shows that survey participants had differing opinions on how quantum computing could transform target identification. Some respondents agreed 46.4%, or strongly agreed 18.5%, that its ability to handle large, complex biological datasets gives it transformative potential. However, many remained neutral (23.8%) or disagreed (11.3%), citing current issues with infrastructure, accessibility, and technological maturity. The range of responses indicates cautious optimism: while quantum computing is viewed as a disruptive force, its practical use in drug development has not yet fully emerged.

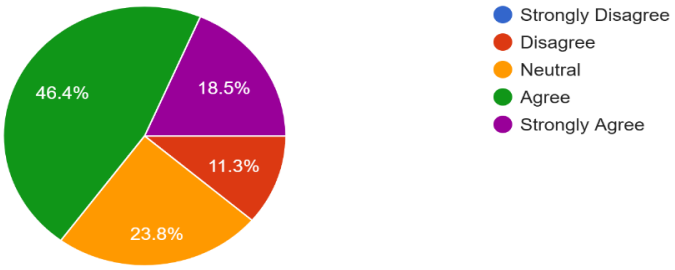

Figure 35. Quantum Computing's Impact on Drug Discovery

Section 20: Primary Barrier to Adopting Advanced AI Technologies

In Figure 36, the column chart shows that respondents identified many obstacles to using advanced AI technologies in drug research. High costs were the main barrier, especially for smaller companies with limited resources. Lack of knowledge and technical difficulties were also often mentioned, highlighting gaps in the specific skills needed for technologies like quantum computing and generative artificial intelligence. Several participants noted the lack of clear development frameworks as a source of regulatory uncertainty. The findings suggest that the industry's adoption of advanced AI is being slowed by a combination of technological, financial, and regulatory challenges.

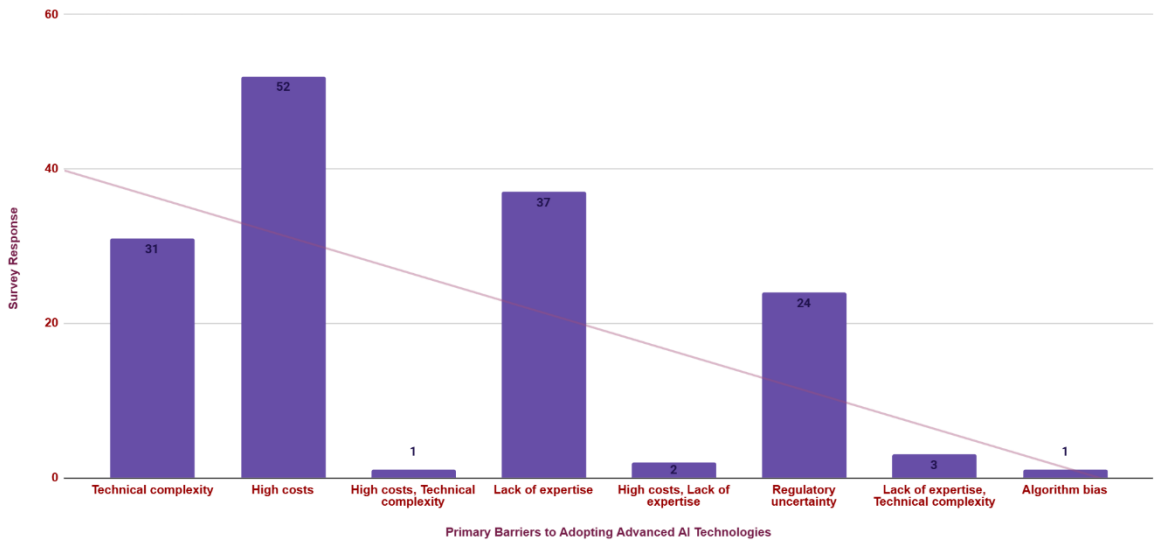

Figure 36. Primary Adoption Challenges for Advanced AI

Section 21: Significance of PDPA Compliance

According to the survey's findings, the pie chart in Figure 37 shows that most participants believed that adherence to India's Personal Data Protection Act (PDPA) was either very important (35.1%) or extremely important (39.1%) for AI-driven drug discovery, indicating strong consensus on its importance. The increasing reliance on patient and clinical datasets, where data security and privacy are vital, is reflected in this emphasis. A smaller percentage of respondents rated compliance as relatively significant, suggesting that some businesses might prioritise operational efficiency over regulatory adherence. Only a small portion of respondents

considered PDPA to be insignificant. These results highlight the importance of data governance and privacy protections in guiding the biopharmaceutical industry's intelligent use of AI.

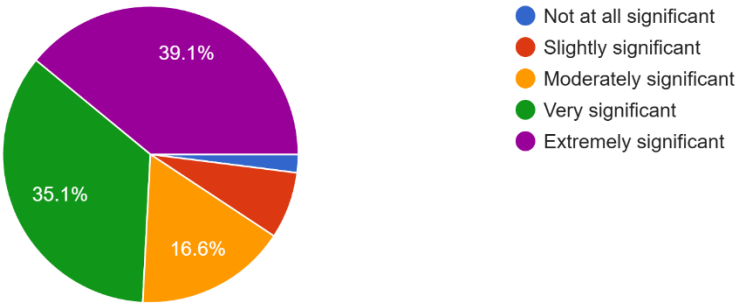

Figure 37. PDPA Adherence in Biopharma AI

Following India's PDPA was deemed necessary to protect sensitive patient and genetic data while fostering trust. While most respondents stated that ethical and responsible AI integration in biopharmaceutical R&D depends on compliance, others believed that compliance is a resource-intensive requirement that could hinder research progress.

The pie chart in Figure 38 shows different opinions about protecting private information in AI-driven drug discovery. Most respondents highlight how essential it is for ethical use, compliance, and trust, especially in cross-border collaborations, and how necessary it is. Other common points on safeguarding private patient data in clinical AI applications include anonymisation, training requirements, and regulatory clarity.

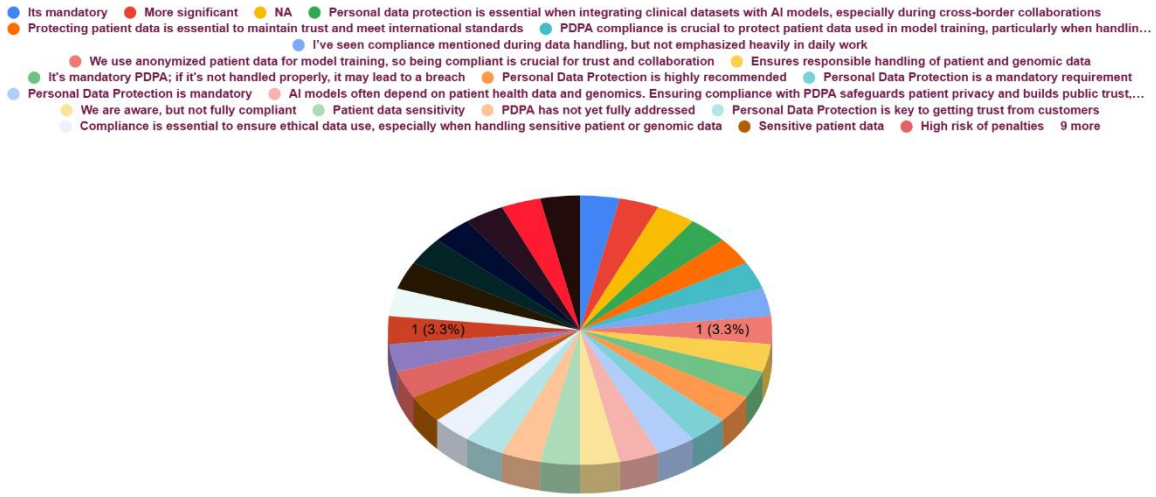

Figure 38. Reasons for Ensuring Confidentiality in AI Use

Section 22: Compliance with CDSCO Guidelines

The pie chart in Figure 39 shows that 71.5% of respondents support AI adoption in their industry, while 19.2% are unsure and only 9.3% oppose it, indicating strong overall acceptance. According to most respondents, their companies follow CDSCO recommendations for AI-driven drug discovery, typically by adhering to legal requirements and validating AI models. Due to limited regulatory understanding or evolving AI frameworks, a smaller group reported non-compliance or expressed doubts. To ensure AI outputs meet both security and efficiency standards, compliance procedures often involve thorough reporting and validation processes. These findings demonstrate that while ongoing guidance from authorities is essential for widespread industry adoption, regulatory alignment is crucial for effective AI integration.

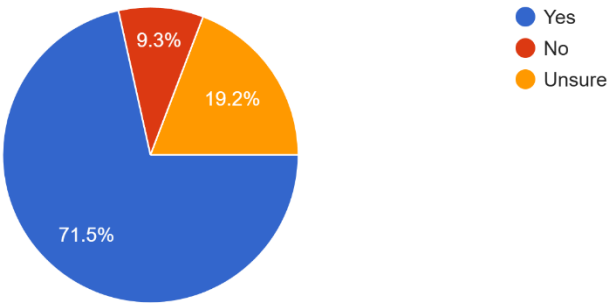

Figure 39. AI Adoption and Regulatory Alignment

The organisational adherence to CDSCO guidelines is shown in the pie chart in Figure 40; the largest segment, 27.2%, indicates full compliance. Other responses are seen in different areas, such as ongoing audits, documentation efforts, and partial adherence. Each color-coded category provides a clear understanding of how companies meet regulatory requirements, highlighting specific aspects of compliance.

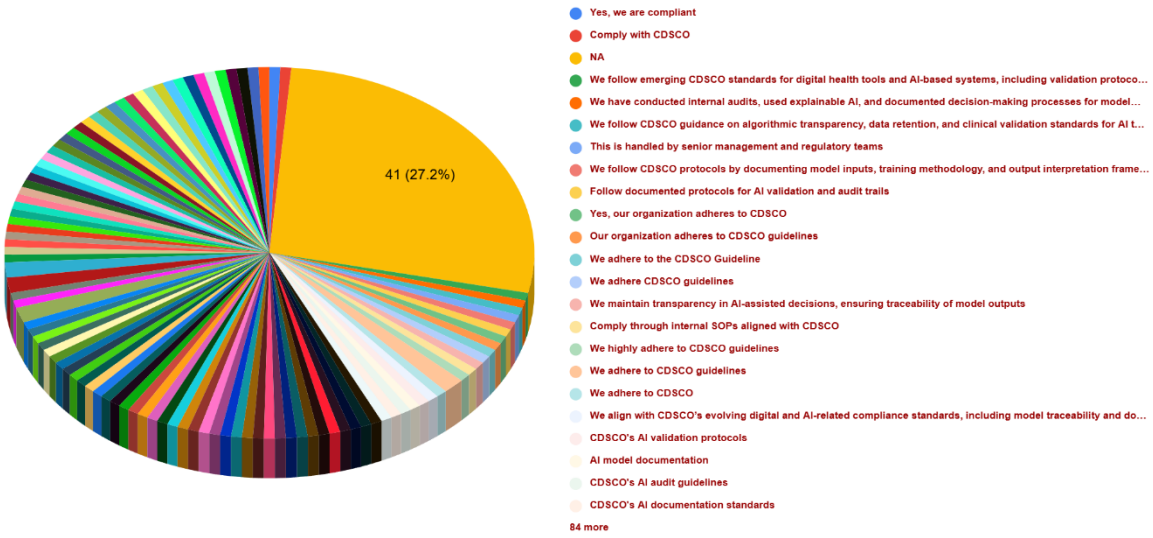

Figure 40. Organizational Compliance with CDSCO Guidelines

Section 23: Primary Ethical Concern in AI-Driven Drug Discovery

The bar chart in Figure 41 shows that responders identified several ethical concerns with AI-driven drug discovery. Data privacy ranks highest with 49.7% of responses, followed by algorithm bias at 31.1%. Fewer respondents raised concerns about unequal access to medicines, which could have wider societal effects. These findings emphasise the need for ethical considerations, especially transparency, fairness, and data security, in the responsible use of AI in the biopharmaceutical industry.

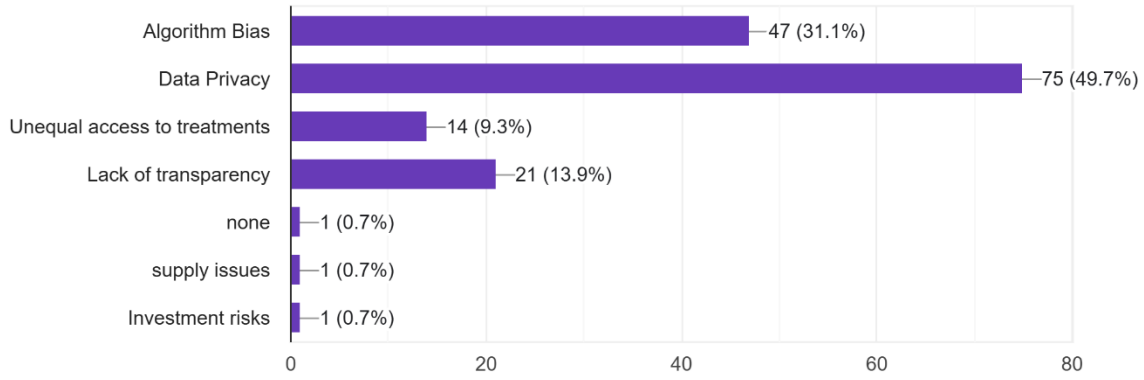

Figure 41. AI Ethics and Data Concerns

Section 24: Measures to Ensure Data Privacy

According to survey results, the column chart in Figure 42 illustrates organisations' use of a wide range of data protection strategies in AI-driven drug discovery. Data anonymisation and encryption are the most common techniques, followed by periodic audits and restricted access. The small proportion of respondents who reported taking no specific action indicates potential flaws. These strategies demonstrate a proactive approach to ensuring regulatory compliance, reducing risks associated with AI integration, and protecting patient and research data. Building trust, maintaining compliance, and supporting the long-term use of AI in the biopharmaceutical sector all depend on having strong data privacy rules.

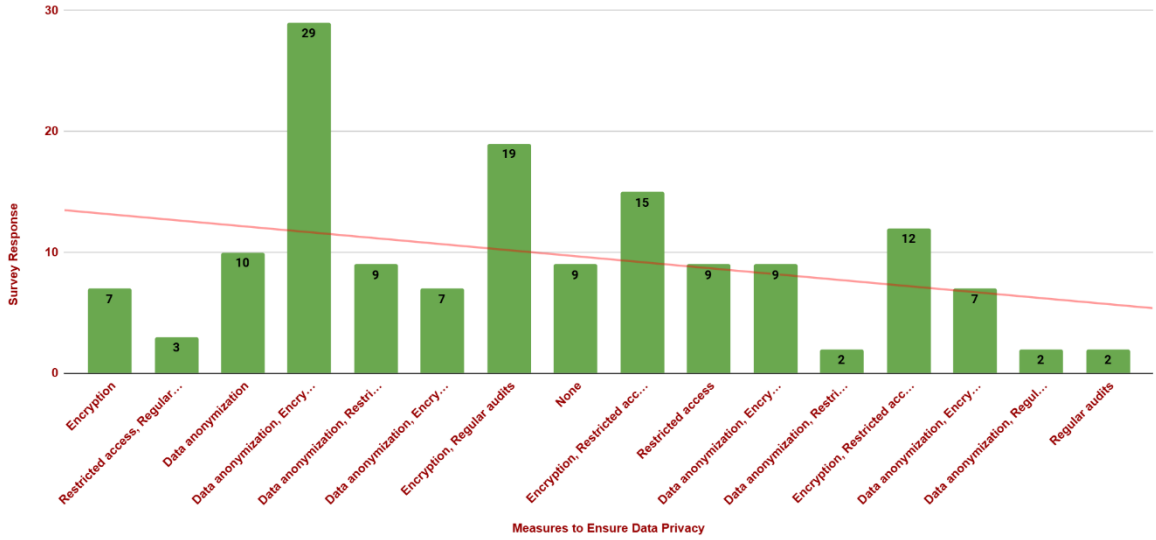

Figure 42. Data Privacy Strategies in Indian Biopharma AI

Section 25: Initiatives to Promote Ethical AI Use

In India's biopharmaceutical industry, responses shown in the pie chart in Figure 43 offer various suggestions for improving AI regulation in pharma, including national guidelines that focus on advancing ethical AI standards, regulatory guidance, and transparency procedures. Additional recommended actions involve improving data quality, providing bias mitigation training, and fostering partnerships between industry and academia to ensure responsible AI development. Several participants emphasised the importance of ethical oversight committees and knowledge sharing across industries. Overall, these responses indicate that to address ethical concerns and encourage responsible AI use in drug research, organised regulations and proactive governance systems are crucial.

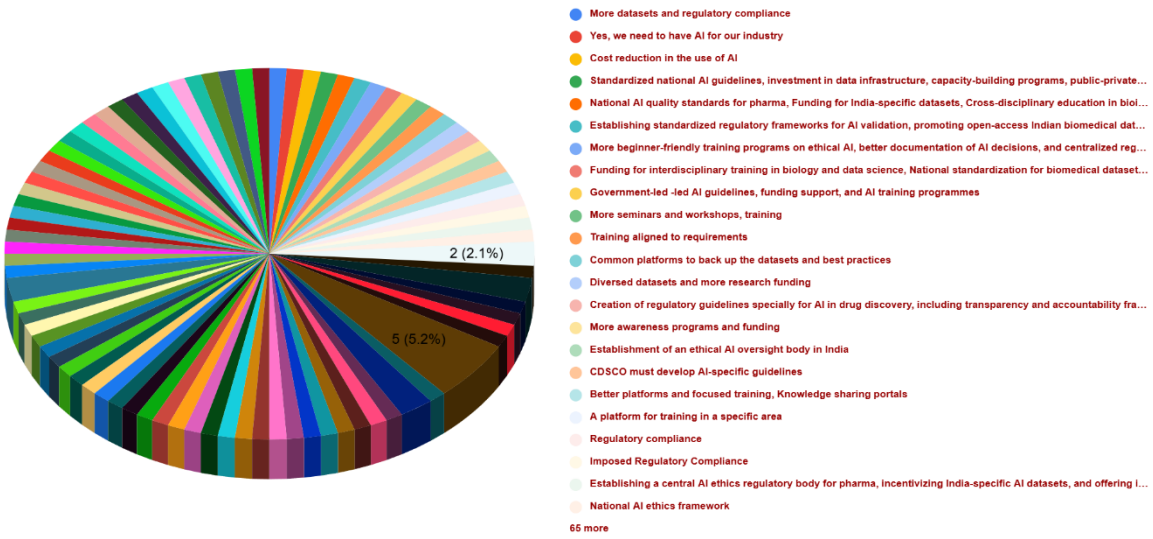

Figure 43. Suggestions for Improving the AI Framework in Indian Biopharma

4.2 Statistical Analysis

To examine whether professional role influenced AI adoption levels, a Chi-Square Test of Independence was conducted. Results (X^2=1.74, p=0.78) indicate no statistically significant relationship, suggesting that adoption levels are similar across scientists, managers, and analysts, and variations are due to chance rather than role-based differences.

4.2.1 Chi-Square Test: Association Between Role and AI Adoption

H0: There is no relation between professional role and AI adoption level.

H1: There is a relation between professional role and AI adoption level.

Result: $X^2(4, N=89) = 1.74$, $p = 0.78 > 0.05$.

Decision: Fail to reject H0

This indicates that the professional role (scientist, manager, analyst) is not significantly associated with the level of AI adoption (pilot, full, none). Variations observed are likely due to chance, suggesting the role is not a determining factor for AI adoption in this sample.

Summary

The findings show that the biopharmaceutical sector in India is adopting AI in a centralised yet multidisciplinary manner, with managers, scientists, and analysts driving most pilot or small-scale projects. Mid-career professionals are speeding up adoption and heavily depend on ML and DL, even as generative AI advances and quantum computing remains aspirational. The focus on oncology in therapeutic applications aligns with global goals, but India's reliance on

foreign AI vendors and lack of academic collaborations highlight its own limitations. AI has already enhanced accuracy and efficiency, with small gains in predictive reliability and quicker target identification, though cost savings are still limited by infrastructure and data preparation costs.

Despite advancements, several obstacles remain. Scalability is limited by infrastructural constraints, a shortage of qualified specialists, and data quality issues, especially due to the absence of datasets unique to India. Although respondents believe that generative AI is the most promising technology for the near future, high costs and unclear regulations hinder the deployment of advanced tools. While governance practices are still inconsistent, a strong understanding of PDPA compliance, confidentiality protections, and CDSCO alignment demonstrates a willingness for responsible AI use. Overall, the findings support the study's hypothesis: AI enhances accuracy and efficiency, but its transformative potential in India depends on overcoming infrastructural, data, and regulatory barriers.

4.3 Secondary Data Analysis

AI Applications in Drug Discovery for Target Identification within Indian Biopharmaceutical Companies

4.3.1 Biocon: Integrating Machine Learning into Target Validation and Molecule Optimisation

Artificial intelligence (AI) has been actively integrated by Biocon (Biocon, 2018) into its drug discovery efforts, especially to improve target validation and identification. Researchers can find patterns and correlations that guide the choice of therapeutic targets by using AI to process large biological information, including proteomics, genomes, and clinical trial data. To reduce the risk and inefficiency associated with conventional target identification approaches, machine learning models assist in prioritising targets based on expected effectiveness, safety, and feasibility for further development (Syngene, 2024)

Biocon benefits from AI in both target discovery and chemical design optimisation. The company (Biocon, 2018) may focus on compounds that have the best probability of succeeding by using prediction algorithms that mimic the interactions between target proteins and candidate molecules. The preclinical stage is accelerated, and drug candidate modifications are made possible by cutting down on the time spent on repeat laboratory testing (Dr. Rajendra

Pratap Gupta, 2025). As a result, Biocon can improve its research procedure while controlling development costs, which is essential in the competitive pharmaceutical industry.

The company's clinical trial strategy (Biocon, 2009). It is also supported by AI, which analyses patient profiles, historical data, and biological features. Finding the best study volunteers, maximising dosing schedules, and predicting adverse effects are all made easier by this. The efficiency and predictive accuracy of Biocon's drug development process can be enhanced by integrating AI-driven insights into the preclinical and clinical stages (Viveka Roychowdhury, 2025).

In general, the pharmaceutical industry's shift toward data-driven, technologically enabled research is reflected in Biocon's (Biocon, 2022) usage of AI. The company can increase the chances of trial success, lower costs, and speed up discovery timelines by incorporating AI into target identification and chemical optimisation. Biocon's efforts show how AI may change traditional drug development methods into more inventive, efficient, and predictive procedures, highlighting the useful advantages of implementing AI in the biopharmaceutical industry.

4.3.2 Dr. Reddy’s Laboratories: AI-Assisted Platforms for Early-Stage Drug Discovery

Artificial intelligence (AI) has been adopted by Dr. Reddy's Laboratories (Sharma, 2024) to improve its drug development procedure, especially in the identification and confirmation of therapeutic targets. The company has created an AI-assisted platform through its subsidiary Aurigene that speeds up early-stage research by fusing machine learning models with molecular synthesis knowledge. In order to find possible drug candidates and forecast their effectiveness against certain targets, Dr. Reddy's uses artificial intelligence (AI) algorithms to process large compound libraries and biological datasets. Researchers can spend less time and money on less promising topics by concentrating on the most promising ones, because of this predictive approach. Additionally, (Jayati Dubey, 2025), by simulating interactions between chemicals and target proteins, the AI platform aids in candidate optimisation. This makes it possible to refine molecules more quickly, reducing the need for wasteful laboratory testing and promoting more effective preclinical research. In addition to improving target validation accuracy, Dr. Reddy's may expedite research workflows by using AI to inform chemical selection (Viveka Roychowdhury, 2025).

AI also assists (Swati Bharadwaj, 2024) the company is planning drug trials by analysing patient data, historical outcomes, and molecular profiles. This helps identify suitable trial participants, optimise dosing plans, and anticipate potential side effects in compliance with legal standards for safety and efficacy.

The pharmaceutical industry's (Dr. Reddy's Laboratories, 2025), the move toward data-driven, predictive approaches to drug discovery is reflected in Dr. Reddy's AI activities. The business increases productivity, lowers development risk, and speeds up the discovery of new treatments by incorporating AI into target selection and optimisation. These initiatives establish Dr. Reddy's as a progressive pioneer in AI-driven drug discovery by showcasing how computational intelligence may improve pharmaceutical research's speed and accuracy (Informatica, 2025).

4.3.3 Sun Pharmaceutical Industries: Leveraging Artificial Intelligence for Target Discovery

The use of artificial intelligence (AI) for drug discovery, with an emphasis on target identification, has been pioneered by Sun Pharmaceutical Industries. The business has aided in the creation of AIRA Matrix, an AI-driven business owned by its creator that uses deep learning and machine learning algorithms to speed up research and development (Krishnan, 2021). Sun Pharma can identify possible treatment targets that traditional approaches would overlook by analysing large biological datasets, such as proteomics, genomes, and clinical data, through the integration of artificial intelligence (AI). The time and risk involved in early-stage drug discovery are decreased by using this prediction approach, which enables researchers to sort targets according to efficacy, safety, and practicality (Viveka Roychowdhury, 2025).

AI helps in molecule design in addition to target discovery by predicting how compounds will interact with specific targets, which speeds up the iteration and optimisation of therapeutic candidates. Because less expensive laboratory testing is required, this expedites the preclinical phase and reduces development expenses. To identify the best candidates, optimise dose, and anticipate potential negative effects, AI also assists with the planning of clinical trials by analysing patient data and previous outcomes (Goodpaster, 2021).

Sun Pharma's AI efforts serve as an example of a larger industry trend that uses computer intelligence to increase drug discovery's effectiveness, precision, and creativity. The company speeds up the development process and raises the chance of clinical success by incorporating

AI into target selection, molecule design, and trial optimisation. These initiatives demonstrate how artificial intelligence (AI) might accelerate the development of new treatments by transforming conventional pharmaceutical research into a more data-driven, predictive method (Krishnan, 2021).

Summary

The secondary research shows how leading Indian biopharmaceutical companies, including Biocon, Dr. Reddy's Laboratories, and Sun Pharmaceutical Industries, are using artificial intelligence to enhance target identification in drug discovery. By applying machine learning to identify patterns in complex biological data, Biocon improves chemical optimisation and target validation while aiding in clinical trial preparation. Through its subsidiary Aurigene, Dr. Reddy's uses AI to speed up preclinical research and predict target validation. Sun Pharma focuses on prioritising targets, analysing biological datasets, and optimising chemical development with AI-driven platforms like AIRA Matrix. The use of AI by these companies shortens research timelines, reduces development risks, and increases productivity, reflecting the industry's broader move toward data-driven, predictive approaches in pharmaceutical innovation.

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5. CONCLUSION

This study analysed the parameters influencing AI-driven target identification in the biopharmaceutical sector of India. The use of AI, its effects on the precision and effectiveness of research, operational and technical difficulties, opportunities for technological development, and associated ethical and legal concerns were all covered. With the utilisation of a survey-based approach and experts from technological, scientific, and administrative backgrounds, and case study insights from top Indian biopharmaceutical companies, the study offers a thorough evaluation of the opportunities and challenges associated with AI in Indian drug discovery.

Adoption is a lengthy and complex process influenced by infrastructure capacity, organisational strategy, regulatory frameworks, and technological readiness, according to the findings. Although AI is clearly in demand, its successful implementation depends on enablers like computational infrastructure, high-quality data, and highly trained professionals. These align with global research but also highlight challenges unique to India.

Technology maturity, strategic priorities, and infrastructure all influence adoption, which is growing but remains uneven. While generative AI shows great potential, the most established technologies are machine learning, deep learning, and natural language processing. AI's potential is being addressed with vital healthcare needs through applications focused on high-burden therapeutic areas like oncology and infectious diseases. However, AI is not fully integrated into R&D pipelines; it is mainly supplementary.

India's AI environment heavily depends on external partnerships. The frequency of collaborations with foreign suppliers surpasses that with domestic academic or research institutions, indicating a lack of local innovation ecosystems and reliance on outside expertise. This pattern highlights the need for ongoing domestic investment in research capabilities and computational infrastructure.

Adoption of AI has shown tangible benefits, including better target identification, shorter discovery times, and cost savings, especially during early-stage hypothesis development and target prioritisation. These findings match global data showing that AI can promote innovation. However, financial benefits are still emerging because infrastructure, data collection, and specialised expertise costs often exceed current savings.

There are still significant challenges to implementing and adopting AI in drug discovery for target identification in the Indian biopharmaceutical industry. Data fragmentation, the lack of Indian-specific biological datasets, and inadequate infrastructure, especially in high-performance computing with secure storage, hinder scalability. The biggest skill gap is in advanced AI and computational biology, which highlights the need for workforce development. Realistic adoption is essential since high costs and unclear legal frameworks further lower expectations.

In the future, cutting-edge technologies will present both opportunities and challenges. Through molecular design and predictive modelling, generative AI offers revolutionary possibilities. Although it remains in its early stages, quantum computing can analyse biological complexity at previously unreachable scales, and graph neural networks might solve network-based biological problems. These advancements indicate a dynamic and evolving field that must be adopted gradually and strategically, supported by infrastructural and regulatory frameworks.

Legal and ethical considerations are vital for sustainable integration. Tackling issues like bias, data privacy, and algorithmic transparency demands strong governance. While valuing national data protection laws and regulatory norms is important, inconsistent compliance emphasises the need for consistent, regulated procedures. Proper governance ensures AI advances speed up discoveries while maintaining equity, transparency, and social responsibility.

In India, AI-driven target identification remains in its early stages due to challenges with data, infrastructure, skills, and regulations. Although its dependence on external platforms suggests potential for strategic growth, its integration with national healthcare plans underscores its importance. India needs to invest in workforce development, eco-friendly infrastructure, indigenous innovation, and stronger ethical and regulatory frameworks to fully realise AI's transformative potential. AI could accelerate drug discovery and position India as a global leader in pharmaceutical innovation, based on the findings and analysis from participants' survey responses and case study data.

5.1 Recommendations

AI-driven target identification aims to reach its full potential in India's biopharmaceutical sector; this study highlights several concerns that require attention. First, strengthening the data infrastructure is essential. Centralising high-quality biomedical datasets, including data unique to India, will improve the accuracy, coherence, and relevance of AI outputs. The second step

involves developing skills. Investing in multidisciplinary training in computational biology, artificial intelligence, and pharmaceutical sciences can help bridge the skills gap that has become a major obstacle.

Third, the computational infrastructure needs upgrading. Lower costs and the assurance that smaller organisations can benefit from AI will come from the availability of secure cloud systems and high-performance computers, possibly facilitated by public-private collaborations. Fourth, India must balance its reliance on foreign AI vendors with developing its skills through stronger industry-academia connections. This will foster the growth of more innovative and self-reliant domestic ecosystems.

Finally, it is essential to establish clear regulations and ethical governance. While adaptable regulatory frameworks that evolve with technological advancements will build confidence for broader adoption, industry-wide standards for transparency, fairness, and reducing bias will be put in place to strengthen trust. Together, these measures provide an effective strategy for successfully and ethically integrating AI into India's biopharmaceutical industry for AI-driven drug research for target identification.

5.2 Limitations of the Study

Although the study offers valuable information, it has limitations. Its cross-sectional design makes it hard to see how practices change over time as laws and technology develop, because it only captures adoption trends at a specific moment. The quantitative survey method is useful for identifying trends, but it doesn't provide as much insight as qualitative methods like interviews.

There are restrictions on the sampling's scope as well. The survey might not accurately reflect the entire biopharmaceutical landscape, especially smaller companies or underrepresented regions, despite the participation of various qualified professionals. Furthermore, some findings, particularly those related to generative AI and quantum computing, may quickly become outdated due to the rapid pace of AI technology development.

5.3 Suggestions for Future Research

Future research should expand on these findings using various approaches. Longitudinal studies could monitor adoption and outcomes as AI progresses, providing insights into changes in cost-effectiveness, accuracy, and patient impact. Case studies of successful implementations

in Indian biopharmaceutical companies would also offer valuable information and best practices for the sector.

Cross-country comparisons can further enhance understanding by comparing India's progress with other emerging economies and exploring its strengths and weaknesses. Using qualitative methods such as surveys or interviews alongside the quantitative themes identified here would provide deeper insights into organisational, ethical, and regulatory processes.

Finally, research should assess the importance of data visualisation and storytelling in decision-making. Effective visualisation not only improves academic communication but also helps government officials, regulators, and business professionals understand complex findings more easily. Together, these methods will advance scholarly knowledge and support the practical development of AI-driven drug discovery in India.

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APPENDICES

GRIFFITH COLLEGE DUBLIN

Innopharma education

GRIFFITH COLLEGE

Ethics Application & Declaration Form

DISSERTATION TITLE: AI-DRIVEN TARGET IDENTIFICATION: REVOLUTIONISING DRUG DISCOVERY IN INDIA'S BIOPHARMACEUTICAL INDUSTRY

RESEARCHER'S NAME: SINDU SELVARAJ

PROGRAMME OF STUDY: MSc in Digital Transformation

SUPERVISOR'S NAME: Dinesh Reddy

DECLARATION:

The information in this application form is accurate to the best of my knowledge. I undertake to abide by the principles outlined by Innopharma/Griffith College ethics policy in my research dissertation. I confirm that I have completed a full ethics assessment for my research dissertation as per the college guidelines. I will not begin my primary research until such approval from my supervisor and/or ethics Committee has been obtained.

I pledge to carry out my research according to the Innopharma/Griffith College academic integrity standards. Any results presented in my dissertation will be from my own, original research, I will reference and/or acknowledge any material or sources used in its preparation and I will not plagiarise the work of anyone else.

For Student:

STUDENT SIGNATURE: 

DATE: 09 July 2025

The research contained within this research dissertation proposal has been approved.

For Supervisor:

Ethics Committee Approval Required: Yes [ ] No [x]

SUPERVISOR SIGNATURE: 

DATE: 09/07/2025

GRIFFITH COLLEGE DUBLIN

For Ethics Committee (if required):

Ethics Committee Approval Given: Yes ☐ No ☐

ETHICS COMMITTEE MEMBER SIGNATURE:

DATE:

NOTE: Supervisors are responsible for ensuring their students fill in this form correctly and that all ethical areas have been considered.

SECTION 1: DESCRIPTION OF RESEARCH STUDY

1.1 Purpose and objectives of research

Purpose:

In India's biopharmaceutical sector, this research aims to critically assess how artificial intelligence (AI) might improve target identification during the drug discovery process. Conventional target identification techniques can be costly, time-consuming, and prone to inefficiencies. AI can improve accuracy and efficiency by evaluating vast biological datasets, which helps speed up the discovery of new drug targets. Although AI innovation is supported by India's robust biopharma and IT sectors, there are a few obstacles that prevent widespread implementation of AI, such as algorithmic bias, low-quality data, a shortage of qualified workers, and unclear regulations. Additionally, it will assess the ethical and legal issues necessary for responsible and safe use, as well as prospects for AI-driven advancements. To promote India's aspirations to become a global leader in biopharmaceutical innovation and to align with international best practices in precision medicine, the goal is to make strategic suggestions for promoting AI integration into the country's drug development ecosystem.

Objectives:

1. Evaluate AI adoption in India's Biopharmaceutical Industry: Analyse the extent to which Indian biopharmaceutical companies are implementing AI-driven target identification technologies, noting adoption rates, trends, and key players.
2. Assess AI's impact on accuracy and efficiency of drug discovery: Investigate how AI enhances the accuracy of target identification over conventional techniques, measuring improvements in cost-effectiveness, timeline reduction, and precision.
3. Identify technical and operational challenges: Consider the barriers to AI implementation, including a lack of standards, algorithm bias, infrastructure limitations, and data quality issues.
4. Explore future AI advancements for target identification: Examine how advanced AI tools like deep learning, generative models, and quantum computing could enhance the drug-discovery process in India.
5. Evaluate Regulatory and ethical considerations: Analyse India's legal framework for integrating AI into biopharmaceutical research, considering data privacy problems, ethical considerations, and policy suggestions for a more efficient deployment of AI.

1.2 Research methodology:

This research takes a pragmatic philosophical stance, employing a mixed-methods approach that combines positivist and interpretivist components to produce useful results. From 150 to 200 Indian biopharmaceutical experts (managers, scientists, and data analysts) with at least two years of expertise with AI applications or drug discovery, quantitative data will be gathered via an online survey utilizing Qualtrics or Google Forms. Utilizing purposive and snowball sampling, participants will be found via LinkedIn, industry newsletters, email invitations, and professional networks like NASSCOM. To evaluate AI adoption rates, efficiency implications, technological hurdles, and regulatory perspectives, multiple-choice, Likert-scale, and numerical input questions will be employed.

A case study examination of 3 to 5 Indian biopharmaceutical businesses (such as Biocon, Dr. Reddy's, and SMEs) with a track record of using AI in drug discovery would be used to collect qualitative data. Data will come from publicly accessible sources such as peer-reviewed studies, industry reports (like NASSCOM), annual reports, and press announcements. Data will be extracted using a standardized form that focuses on the adoption, results, difficulties, and ethical/regulatory concerns of AI.

To ensure accessibility and maximize response rates, the survey will take 10 to 12 minutes to complete. To find trends in AI adoption and obstacles, quantitative data will be evaluated using statistical techniques (such as chi-square tests and descriptive statistics) in SPSS. To find themes like infrastructural constraints or regulatory loopholes, qualitative data will be subjected to thematic analysis using NVivo or manual coding. Both datasets will be integrated using a convergent parallel approach to produce thorough results. This method is appropriate for India's varied biopharmaceutical ecosystem since it guarantees empirical rigor while capturing contextual complexities.

SECTION 2: POSSIBLE ETHICAL ISSUES

Answer 'yes' or 'no' to the following questions.

SUBJECT MATTER

Does the research proposal involve:

Research into specific company activities that would be deemed sensitive or confidential	No
Research into politically and/or racially/ethnically and/or commercially sensitive areas	No
Sensitive, personal, professional or corporate issues	No

RESEARCH PROCEDURES

Does the research proposal involve:

Research that might damage the reputation of companies or participants	No
Research that may negatively affect the reputation of Griffith College/Innopharma	No
Use of personal records without consent	No
Use of company data without consent	No
The offer of any inducements to participate	No
Audio or visual recording without consent	No
Using a language other than English	No

PARTICIPANTS

Does the research proposal involve:

People who are not competent and/or fluent in English	No
Does your research group include any of the following vulnerable groups	No

If you have answered NO to ALL questions, please go straight to Section 4.

If you have answered YES to ANY question in SECTION 2, you must fill in SECTION 3.

SECTION 3: STEPS TAKEN TO AVOID ETHICAL ISSUES

3.1. If your ethics relates to ***Subject Matter***, outline your action plan to work around any sensitive issues.

3.2. If your ethics relates to ***Research Procedures***, outline your action plan to deal with possible ethical issues in your research procedures.

3.3 If your ethics relates to ***Participants***, outline how you will protect vulnerable persons or those that do not have English as their first language.

SECTION 4: ABOUT YOUR PARTICIPANTS

4.1. Outline your participant profile and why you have chosen them for this study

The research focuses on two participant groups:

- Survey Participants: R&D or AI deployment managers, scientists, and data analysts with at least two years of working experience in Indian biopharmaceutical companies. The selection of these experts is based on their firsthand understanding of AI adoption, its effects on drug discovery, and related difficulties (e.g., infrastructure, data quality). It guarantees a range of viewpoints on adoption potential and obstacles by incorporating both large companies (like Biocon) and SMEs.
- Case Study Companies: 3–5 biopharmaceutical firms with known AI applications in drug research (e.g., Biocon, Dr. Reddy's, SMEs). Their leadership in the adoption of AI, insights into real-world applications, results (e.g., timeline reductions), and ethical and regulatory considerations are the reasons behind their selection. Data from these businesses that are made publicly available will provide context without necessitating direct stakeholder participation.

4.2 How do you plan to gain access to/contact/approach your participant(s)?

Snowball sampling and purposive sampling will be used to find survey respondents through professional networks. I will approach biopharmaceutical experts by using industry relationships through NASSCOM, LinkedIn, and email invitations. Invitations will outline the goal of the study and highlight how it would further biopharmaceutical innovation in India. Advertisements for the study will be posted on LinkedIn groups and industry newsletters (e.g., the Indian Pharmaceutical Association). Individualized communications will promote involvement and encourage recommendations to other competent experts. For case studies, information will be taken from publicly accessible sources (such as business websites and SEC filings).

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SECTION 5: INFORMATION, CONSENT, AND CONFIDENTIALITY

5.1 **Participant Information Letter (PIL) for participants**

Please confirm below that your information letter covers:

Description of the research topic and method	Yes
Details of what participation will involve	Yes
Rights to anonymity	Yes
Confidentiality	Yes
Rights to withdraw from the research	Yes
The contact details of the researcher and supervisor (if necessary)	Yes

5.2 **Informed Consent Form (ICF) for participants**

Please indicate below if your research requires a signed consent form by selecting the relevant option only:

No signed form needed. Consent collected via checkboxes in the online survey.

1. Do you consent to participate in this study?

   ☐ Yes, I consent to participate

   ☐ No, I do not consent to participate

SECTION 6: STORAGE OF DATA

6.1 How will you store the research data and for how long? How will you manage data protection issues?

All research data will be securely stored on a password-protected electronic device, including survey responses and analysis files. The primary storage location will be a laptop that is appropriately password-protected. A backup copy will be stored on OneDrive (online cloud storage platform) to prevent data loss. For a period of two years, all the research data will be retained after the qualification is granted. This retention period is in place in accordance with the data protection regulations to allow for any further analysis or verification that may be required. The information will be securely and permanently deleted at the conclusion of this period.

1. Anonymization: To guarantee participant anonymity, all recognisable information (such as names and contact information), if any, will be eliminated from the survey data and substituted with distinct identifiers.
2. Password Protection: All electronic documents that contain research data will be password-protected with strong, unique passwords that only the researcher can access.
3. Access to Data: The raw, anonymised data will be sent to Moodle, the college submission platform, as part of the thesis submission for grading and record-keeping purposes.
4. Data Encryption: To prevent unauthorised access to the data, the storage devices (hard drive or cloud storage) will be password-protected.

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SECTION 7: NON-DISCLOSURE AGREEMENT & STUDENT CONSENT

7.1 **Non-Disclosure Agreement (NDA)**

Will the final dissertation contain any information about any source that would warrant the use of a Non-Disclosure Agreement (NDA), e.g., industry-based research?

No

7.2 **Student consent**

If a Non-Disclosure Agreement (NDA) is not required, does the student consent to allow their completed dissertation to be held/published by Innopharma/Griffith College?

Yes

SECTION 8: RECORDING AND RETENTION OF DISSERTATION VIVA

8.1 **Viva Recording**

The Dissertation viva will be recorded. This recording may be used to facilitate assessment by Innopharma staff, a third reader if necessary, and/or if requested by the external examiner for the Programme. The recording will be held in line with current GDPR guidelines and will not be made publicly available.

SECTION 9: DOCUMENT CHECKLIST

NOTE: Applicants must attach the following documents in electronic format to the appendix.

Which documents are added to the appendix? Please tick N/A if not applicable:

9.1 Participant Information Letter (PIL) for participant	Yes
9.2 Informed Consent Form (ICF) for participant	Yes
9.3 Questions/survey for interviewees/focus groups, etc *(can be in draft form)*	Yes
9.4 Any other documents, e.g., Non-Disclosure Agreement	N/A

I confirm that this application is complete, and all required documents are included in the appendix.

For Student:

STUDENT SIGNATURE: 

DATE: 09 July 2025

SECTION 10: APPENDIX

10.1 Survey for Biopharmaceutical Professionals

This study is to assess AI-driven target identification in the Indian biopharmaceutical sector to improve the effectiveness of drug discovery. This study is essential for comprehending the effects of AI and determining adoption strategies, given the expanding biopharmaceutical industry in India and issues like data quality and regulatory limitations. Completing a 10- to 12-minute online survey about AI adoption, its effects, difficulties, and future potential is what participants must do to contribute. The answers will remain anonymous and completely confidential. This survey may help India's biopharmaceutical innovation be advanced and brought into compliance with international precision medicine norms.

10.2 Participant Information Letter

Title of The Study: AI-Driven Target Identification: Revolutionising Drug Discovery in India’s Biopharmaceutical Industry

Dear Potential Participant,

I would like to invite you to participate in a research study conducted as part of my MSc in Digital Transformation at Innopharma/Griffith College. Before deciding, please carefully read this letter to learn about the study's goal and what your participation involves. Please don't hesitate to ask questions if you need additional information or if something is unclear. Take your time determining whether you wish to participate.

Who I Am and What This Study Is About

I am Sindu Selvaraj, a postgraduate student at Innopharma/Griffith College, conducting this research under the supervision of Mr. Dinesh Reddy. The purpose of this study is to evaluate how target identification in the drug discovery process within the biopharmaceutical sector of India can be improved by artificial intelligence (AI). The study looks at the rates of AI adoption, how it affects accuracy and efficiency, operational and technological difficulties, upcoming developments in AI, and ethical and legal issues. As part of my dissertation for the Master of Science in Digital Transformation, this work attempts to support India's biopharmaceutical innovation by conforming to international norms for precision medicine.

What Would Taking Part Involve?

If you consent, you will be required to fill out a 10- to 12-minute online survey using Google Forms or Qualtrics. The survey will ask you about your experience with artificial intelligence (AI) in drug research, including its effects, difficulties, and ethical and regulatory viewpoints. It will include multiple-choice, Likert-scale, and numerical input items. A link to the survey will be sent to you by email or professional networks like LinkedIn, and it is intended to be brief to respect your time. Only your survey responses will be utilized to inform your participation; no audio or video recordings will be used.

Why have you been invited to Take Part?

As a professional (such as an R&D manager, scientist, or data analyst) with at least two years of expertise in AI applications or drug discovery in India's biopharmaceutical sector, you have been invited. Your knowledge of AI

adoption, its impacts, and associated difficulties is invaluable. Professional networks like NASSCOM, LinkedIn, and industry newsletters, as well as recommendations from other experts in the sector, were used to find you.

Do You Have to Take Part?

The decision to participate is completely voluntary. Without facing any repercussions, you are allowed to deny participation, refuse to respond to any questions, or leave the research at any moment. Your professional status and relationship with Innopharma/Griffith College will be unaffected by your choice.

What Are the Possible Risks and Benefits of Taking Part?

Being a participant in this study has no substantial risks. All replies will be anonymised to preserve your privacy, and the poll does not gather any sensitive personal or business information. There are no immediate personal advantages, but by influencing strategies for ethical behaviour and AI integration, your involvement could help India's biopharmaceutical sector grow. The study's conclusions might encourage creativity and be in line with international precision medicine guidelines.

Will Taking Part Be Confidential?

Your answers will be anonymous and kept private. No personally identifying information, such as names or contact information, will be gathered unless consent is obtained; any such information will be substituted with unique identifiers. All information for the study will come from publicly accessible sources or anonymised survey responses; sensitive company data will not be used. The only way confidentiality will be violated is if there is a significant risk of harm or danger to you or others (such as proof of unlawful activity), which is extremely unlikely given the study's purpose. I will use Moodle to exchange anonymized data with my supervisor and the college for grading reasons.

How Will the Information You Provide Be Stored and Protected?

The analysis files and survey answers will be safely kept on a laptop that requires a password, and they will be backed up on OneDrive, a safe cloud storage service. My supervisor and I will be the only ones with access to the encrypted data for research reasons. Consent documents that I have signed (using online checkboxes) will be kept on file until I receive my degree. Following data protection laws, anonymized survey data will be retained for two years after graduation in case another study or verification is required. All data will be permanently erased at the end of this period. The Freedom of Information Act grants you the right to view the information you have provided at any time.

What Will Happen to the Results of the Study?

The findings will be utilized solely for my dissertation, which I will submit to Innopharma/Griffith College for evaluation. The dissertation may be stored in the college library and published online in repositories or e-journals. Neither the dissertation nor any publications will contain any personally identifiable information. To advance knowledge in the field, the findings could be presented at scholarly conferences or included in teaching materials.

Who Should You Contact for Further Information?

For any questions, please contact:

- Researcher: Sindu Selvaraj, [sindu.s.84@gmail.com]

Thank you for considering participation in this study. Your contribution could help shape the future of AI-driven drug discovery in India

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Section 1: Participant Consent

1. ☐ I have read and understood the purpose of this study, which is to assess AI-driven target identification in India's biopharmaceutical industry to improve drug discovery effectiveness, and I am aware of what my participation involves.

2. ☐ I voluntarily consent to participate in this study and agree to respond to the survey questions.

Section 2: Participant Profile

1. **Which of the following best describes your role in the biopharmaceutical industry?**
   a. Manager
   b. Scientist
   c. Data Analyst
   d. Other: _____

2. **How many years of experience do you have in AI applications or drug discovery?**
   a. Less than 1 year
   b. 1–2 years
   c. 2–5 years
   d. 5–10 years
   e. More than 10 years

Section 3: Evaluate AI Adoption in India's Biopharmaceutical Industry

3. **Which AI tools does your organization use for drug discovery? (Select all that apply)**
   a. Machine Learning
   b. Deep Learning
   c. Natural Language Processing
   d. Generative AI
   e. Quantum Computing
   f. None
   g. Other: _____

4. **To what extent is AI integrated into your organization's R&D processes?**

a. Not integrated
b. Pilot stage
c. Partially integrated
d. Fully integrated
e. Unsure

5. **Which therapeutic areas does your organization apply AI to for target identification? (Select all that apply)**
    a. Oncology
    b. Infectious Diseases (e.g., TB, malaria)
    c. Diabetes
    d. Cardiovascular Diseases
    e. Neurological Disorders
    f. Other: _____
    g. None
6. **Does your organization collaborate with external AI platforms (e.g., Insilico Medicine, Benevolent AI)?**
    a. Yes
    b. No
    c. Unsure

If yes, please specify the platforms:

7. **What is the primary motivation for your organization to adopt AI in drug discovery?**
    a. Cost reduction
    b. Time efficiency
    c. Improved accuracy
    d. Competitive advantage
    e. Regulatory compliance
    f. Other: _____

Section 2: Assess AI's Impact on the Accuracy and Efficiency of Drug Discovery

8. **To what extent has AI improved the accuracy of target identification in your organization?**
    a. (No improvement)
    b. 2
    c. 3
    d. 4
    e. 5 (Significant improvement)

Please specify the reason for your response:

9. **By what percentage has AI reduced target identification time in your organization?**
    a. 0%

b. 1–10%
c. 11–20%
d. 21–30%
e. More than 30%
f. Unsure

Please specify the reason for your response:

10. By what percentage has AI reduced R&D costs for target identification?

a. 0%
b. 1–10%
c. 11–20%
d. 21–30%
e. More than 30%
f. Unsure

Please specify the reason for your response:

11. What specific outcomes have you observed from AI use in target identification? (Select all that apply)

a. Identification of novel targets
b. Faster drug development
c. Reduced costs
d. Improved patient outcomes
e. None
f. Other: _____

Section 3: Identify Technical and Operational Challenges

12. What are the primary challenges in implementing AI for target identification? (Select all that apply)

a. Poor data quality
b. Algorithm bias
c. Lack of high-performance computing infrastructure
d. Limited AI expertise
e. Regulatory uncertainty
f. High costs
g. Other: _____

Please elaborate on your response:

13. **What is the most significant barrier to AI adoption in your organization?**
    a. Lack of funding
    b. Limited expertise
    c. Data quality issues
    d. Infrastructure limitations
    e. Regulatory gaps
    f. Other: _____

Please specify the reason for your response:

14. **What is the primary source of data quality issues in your organization?**
    a. Inconsistent data collection
    b. Lack of India-specific datasets
    c. Data fragmentation
    d. Other: _____
    e. None
15. **What specific infrastructure limitations does your organization face? (Select all that apply)**
    a. Lack of high-performance computing
    b. Limited cloud storage
    c. Poor internet connectivity
    d. Other: _____
    e. None
16. **What measures has your organization taken to address algorithm bias?**
    a. None
    b. Training on diverse datasets
    c. Regular audits of AI models
    d. Collaboration with external experts
    e. Other: _____

Section 4: Explore Future AI Advancements for Target Identification

17. **How likely is your organization to adopt advanced AI technologies (e.g., generative AI, quantum computing) in the next 5 years?**
    a. Very unlikely
    b. Unlikely
    c. Neutral
    d. Likely
    e. Very likely

Please specify the reason for your response:

18. **Which advanced AI technology holds the most promise for drug discovery?**
    a. Generative AI
    b. Quantum Computing

c. Graph Neural Networks
d. Other: _____
e. None

19. **To what extent do you agree that quantum computing will revolutionize target identification?**
    a. Strongly Disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree
20. **What is the primary barrier to adopting advanced AI technologies?**
    a. High costs
    b. Lack of expertise
    c. Technical complexity
    d. Regulatory uncertainty
    e. Other: _____

Section 5: Evaluate Regulatory and Ethical Considerations

21. **How significant is compliance with India's Personal Data Protection Act (PDPA) in AI-driven drug discovery?**
    a. Not at all significant
    b. Slightly significant
    c. Moderately significant
    d. Very significant
    e. Extremely significant

Please specify the reason for your response:

22. **Does your organization comply with CDSCO guidelines for AI-driven drug discovery?**
    a. Yes
    b. No
    c. Unsure

If yes, please specify how:

23. **What is the primary ethical concern in AI-driven drug discovery?**
    a. Algorithm bias
    b. Data privacy
    c. Unequal access to treatments
    d. Lack of transparency
    e. Other: _____
24. **What measures does your organization take to ensure data privacy? (Select all that apply)**
    a. Data anonymization
    b. Encryption

c. Restricted access
d. Regular audits
e. Other: _____
f. None

25. **What changes or initiatives would be most helpful in promoting ethical AI use in India's biopharmaceutical industry?**
    a. Open-ended response: _____

10.2: Sample Size Calculations

Cochran's Formula

$$n = \frac{z^2 * p * (1-p)}{e^2}$$

- n = Sample Size
- z = Confidence Level
- p = Population Proportion
- e = Margin of Error

Biopharmaceutical Professionals: 150-200 participants

In R&D positions, the Indian biopharmaceutical sector employs about 50,000 experts (NASSCOM, 2024). According to adoption trends in India's biopharmaceutical industry, 30% of these individuals are thought to be working in drug discovery or AI applications. This estimate is modest to provide sufficient representation for an exploratory investigation, considering the specialized focus on target identification driven by AI.

- Z = Confidence Level = 95% (z-score = 1.96)
- p = Population Proportion = 30% (0.3)
- e = Margin of Error = 5% (0.05)

$$n = \frac{(1.96^2 * 0.3 * (1-0.3))}{0.05^2}$$

$$n = \frac{(3.8416 * 0.3 * 0.7)}{0.0025}$$

$$n = \frac{0.806736}{}$$

0.0025

$n \approx 322.69$

$n \approx 323$

A target sample size of 150–200 participants is considered appropriate to account for the exploratory character of the study and possible low response rates (common in online surveys targeting busy professionals). As specified in the research methodology, this range strikes a mix between statistical reliability and practical feasibility, guaranteeing enough data to detect trends in AI adoption, effect, obstacles, and regulatory/ethical considerations using statistical tests like chi-square.