Promoting Innovation and Deployment of Low Carbon Technologies

(UNIDO-BEE-GEF PROJECT)

Facility For Low Carbon Technology Deployment

A STUDY OF
TECHNOLOGY TRANSFER CENTRES
TO INCREASE COMMERCIALIZATION OF INNOVATIONS

DST-CENTRE FOR POLICY RESEARCH
PANJAB UNIVERSITY CHANDIGARH

DST- Centre for Policy Research Panjab University, Chandigarh

DISCLAIMER

The present report has been prepared to provide information about studying Technology Transfer Offices (TTOs) in India. The study has been conducted by a team of researchers from DST-CPR, Panjab University, under the leadership of the co-ordinator DST-CPR and with active support from the UNIDO-FLCTD Project. The report is compiled based on exhaustive desk research and questionnaire responses received from TTO teams during in-person visits and discussion sessions. Particular emphasis has been on referring to the latest information (till the compilation of the report) available in the form of papers, articles, and manuals in print/digital/website. Further, to check the data's validity, accuracy, completeness, or fitness, respective TTOs were contacted, and authentication by the respective TTOs for omissions, inaccuracies or other errors related to the data was conducted.

The content and findings presented in this document are based on the information obtained from primary and secondary sources and do not necessarily reflect the views of DST-CPR, UNIDO FLCTD Project, Panjab University or the Bureau of Energy Efficiency. This report does not express the views of UNIDO, its Secretariat, its offices in India and elsewhere, or any of its Member States.

FLCTD

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DST CPR

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भारत 2023 INDIA
अभय बाकरे, आईआरएसईई
महानिदेसक
ABHAY BAKRE, IRSEE
Director General

सत्यमेव जयते
Azadi Ka Amrit Mahotsav

ऊर्जा दक्षता ब्यूरो
(विद्युत मंत्रालय,भारत सरकार)
BUREAU OF ENERGY EFFICIENCY
(Ministry of Power, Government of India)

MESSAGE

It is a pleasure moment to pen few words starting with, congratulating Department of Science and Technology (DST), Centre for Policy Research (CPR) at Punjab University for conducting the needful study focussing on strategic means of technology transfer and commercialization of innovations. Complementing our GEF funded program "Facility for Low Carbon Technology Deployment (FLCTD), jointly implementing by Bureau of Energy Efficiency and United Nation Industrial Development Organisation (UNIDO).

Since its inception, FLCTD program has been conducting rigorous exercise to recognise and award innovative – clean – Low carbon technologies, under selected vertical of areas possessing high replication- scalable- commercializing potentials. As on today the program has awarded 70 innovations and supporting them towards commercialization.

BEE believes these 70 and more innovations will be instrumental in bringing transformational changes in the technology market and support in enhancing energy efficiency and mitigation of GHG emissions. As a reader, you are aware India is a climate leader demonstrated meeting our nationally determined goals in the past and pledged for even more challenging goals to achieve the Net-Zero Emissions country by 2070. In this regard, Innovation assumes a greater role in bringing out low-carbon technologies. Building a robust technology transfer ecosystem in India is crucial for driving innovation and economic growth.

The study has summed up with thoughtful recommendations to strengthen the function of technology transfer and deepen industry-academia partnership, comprehensive policy ecosystem for technology transfer, widening stakeholder network to support grassroot level and indigenous innovations.

Congratulation to FLCTD Team, UNIDO and faculty of DST-CPR Punjab University for successful completion of the study.

Abhay Bakre

Shri Abhay Bakre
Director General

29.11.2023

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नीति समन्वय एवं कार्यक्रम प्रबंधन प्रभाग
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विज्ञान और प्रौद्योगिकी मंत्रालय
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Senior Adviser & Head
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MESSAGE

Innovation ecosystems are experiencing rapid and significant evolution on the global scale. The Transfer of Technology and knowledge plays a pivotal role in generating socio-economic value from these innovations. The dynamic nature of innovation and Technology Transfer is instrumental in shaping a nation's scientific temperament. Over the past few decades, there has been a growing emphasis on Technology Transfer, prompting the scientific community to implement mechanisms that ensure successful knowledge transition from producers to consumers. Keeping this in mind, the study carried out by DST-Centre for Policy Research at Panjab University, Chandigarh will be an asset in understanding the Technology Transfer topography nationally and internationally. It provides valuable insights and actionable recommendations on how we can strengthen Technology Transfer offices, streamline processes, and surmount obstacles to increase the commercialization potential of innovations. The ecosystem for Technology Transfer is evolving considerably over time, adapting to the ever-changing innovation and technology landscape. The ecosystem acts as a catalyst for translating research breakthroughs into practical applications, thereby facilitating advancements in healthcare, communications, sustainability, and other fields. By facilitating the seamless Transfer of Technology, the ecosystem promotes economic growth, advances society, and shapes the future of our interconnected world.

The report highlights the crucial role played by Technology Transfer Offices in bridging the gap between academia and industry. It sheds light on the mechanisms and instruments employed to successfully transfer technology from academia to the industry. It will provide valuable insights to policymakers, enabling them to identify areas that require attention in strengthening the mechanisms that foster innovation and facilitate Technology Transfer in our country. I have witnessed first-hand how Technology Transfer offices are evolving in the Indian Innovation system consisting of a diverse set of innovation actors, especially their role in bridging the gap between academia and industry and generating value. These offices play a crucial role in facilitating the commercialization of innovative ideas, thereby transforming them into tangible products and services that benefit society. In India, the Technology Transfer ecosystem is in its developing phase, and it is crucial to examine its current state in order to reinvigorate it to imbibe the culture of generating value out of scientific knowledge. I applaud the entire team for the publication of the report, "A Study of Technology Transfer Centres to Increase Commercialization of Innovations." It emphasizes the critical role they play in expediting the transition of ideas from research laboratories to the marketplace, thereby enhancing the nation's global competitiveness. I would also like to extend my heartfelt congratulations to DST-Centre for Policy Research, Panjab University for their exceptional work in driving Technology Transfer and promoting the commercialization of innovations.

(Akhilesh Gupta)

Professor Renu Vig
Vice - Chancellor

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MESSAGE

I am delighted to extend my heartfelt congratulations to the DST-Centre for Policy Research at Panjab University, jointly working with the Facility for Low Carbon Technology Deployment Programme (FLCTD), United Nations Industrial Development Organization (UNIDO), on the successful culmination of the project titled "A study of Technology Transfer centres to increase commercialization of innovations."

This comprehensive document highlights our national Technology Transfer attributes, achievements, challenges, and future strategies in innovation and Technology Transfer. The report has mapped the Technology Transfer activities carried out in the Technology Transfer offices across Indian higher academic and research institutes. I am delighted to see the participation of Technology Transfer offices in this exercise, where they have contributed significantly.
Technology Transfer has become an imperative notion for driving the impact of science, technology and innovation pursuits in today's world of generating value out of science and technology. This study will provide insights for cross-learning best Technology Transfer practices amongst the Technology Transfer offices and the international innovation systems.

This project's completion exemplifies DST-Centre for Policy Research, Panjab University's commitment to high-impact research and the development that can be applied to resolve pressing societal issues. The study will benefit policymakers, researchers, and investors by illuminating the dynamics of Technology Transfer, which they can use to better address the challenges encountered during invention commercialization. The success of DST Centre for Policy Research and the important work it does are a source of great pride for our university. The efforts of this Centre are critical to ensuring that our innovations and ideas have a positive impact on society in the years to come as we work to establish a thriving ecosystem that encourages creativity. As we embrace the rapidly evolving innovation and Technology Transfer terrain, I believe this report will be a catalyst for understanding and stimulating the Technology Transfer space and the generation of socio-economic value out of the innovations pursued in the country as per the country’s aspirations and priorities.

(Renu Vig)

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UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

FOREWORD

Over the past decades, the partnership between the Government of India and the United Nations Industrial Development Organization (UNIDO) has evolved to develop and improve the country's industry, energy and agriculture sectors. The adoption of the Sustainable Development Goals by the global community in 2015, specifically SDG9 (industry, infrastructure and innovation) entrusted UNIDO to assist India and its developing country member states with the transition towards Inclusive and Sustainable Industrial Development.

In 2016, UNIDO initiated a project with the Bureau of Energy Efficiency (BEE), titled Facility for Low Carbon Technology Deployment (FLCTD), supported by the Global Environment Facility. One of the project's focus areas is to identify, demonstrate and validate innovative low-carbon technologies for application and commercialization in industrial, commercial and agriculture sectors. The project conducts innovation challenges and identifies the winning innovations with a replication potential while delivering energy savings and emissions reduction. UNIDO provides financial support to the innovation challenge winners and industry connections to conduct field trials and validate the efficacy of the innovation.

Another area of FLCTD project's support is to strengthen India's innovation ecosystem by enhancing technology transfer function in various higher education institutes and research laboratories. The technology transfer process enables pathways to transition technology from institutions to the market.

In 2022, UNIDO partnered with Department of Science and Technology's Centre for Policy Research, based in Panjab University, Chandigarh to conduct a comprehensive study of "Technology Transfer Centers to Increase Commercialization of Innovations".

The study presents an understanding of Technology Transfer ecosystem nationally on the basis of technology transfer activities of various higher education institutes, national research laboratories across India and also studied the Technology Transfer ecosystem in five developed countries based in Asia, Europe and America.

This study is based on primary research is well-supplemented with literature and desk research, and report provides an overview of the *"as-is"* status of the activities in the Indian technology transfer ecosystem. Further, an effort has been made to identify knowledge gaps and implementation challenges faced by the academic and research institutions in technology transfer. A comparative analysis of the innovation ecosystems of developed countries provides areas and points of divergence, which when addressed can strengthen overall National System of Innovation with improved technology transfer function and industry-academia collaboration.

The report is meant to serve as a foundational work to enable further research to support and strengthen the Science Technology and Innovation initiatives of the Government of India to accelerate innovation to achieve energy transition and net-zero emission goals.

Alois MHLANGA
Chief – Climate Technologies Innovation Unit

ACKNOWLEDGMENT

DST- Centre for Policy Research (CPR), Panjab University, Chandigarh would like to extend deepest appreciation to United Nations Industrial Development Organization (UNIDO) in New Delhi, Dr René van Berkel, Country Representative, Mr. Sanjaya M. Shrestha, Industrial Development Officer and Mr. Sandeep Tandon, National Project Manager, Mr. Nitesh Kaushik, National Expert, Technology Transfer with the Facility for Low Carbon Technology Deployment Programme (FLCTD), for giving the opportunity to work upon an ambitious project "A Study of Technology Transfer Centres to Increase Commercialization of Innovations". Gratitude is due for your guidance and funding support to do this extensive study on the vital function of Technology Transfer offices in propelling innovations and commercialization in India and for accomplishing this project successfully.

We would like to express a sincere thanks to Prof. Renu Vig, Vice-Chancellor, Panjab University, Chandigarh, for providing valuable resources to DST-CPR, PU and keeping faith in the vision and activities of this project. We also wish to place on record sincere gratitude towards the Department of Science and Technology (DST), Government of India (GoI) for the support and guidance to achieve the mandates of the Centre and oversight in this study.

We would like to acknowledge the contribution of scientists, faculty members and researchers from the 25 shortlisted institutions for cooperating with us and providing full support and giving us time, and sharing knowledge with us. Their insights have helped to gain deeper insight into the Technology Transfer landscape. We also wish to place on record a special thanks to Prof. Sanjeev Sharma, University Institute of Applied Management Sciences (UIAMS), Panjab University, Chandigarh for his support in statistical analysis and their valuable inputs. Your feedback and support are highly appreciated, and this added substantial outcomes to the project. Everyone who has helped with this project and unwavering backing. We express apologies to those, whose names have been inadvertently missed.

In the end, we are grateful to the team who worked dedicatedly on this project.

Thank you for the hard work, achievements and successes!

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Department of Science & Technology
Govt. of India

DST-Centre for Policy Research
at
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PREFACE

The study was carried out under the project entitled "A Study of Technology Transfer Centres to Increase Commercialization of Innovations" conducted under the Facility for Low Carbon Technology Deployment by UNIDO. The study included both desk-based searches and in-person visits to select Technology Transfer Offices (TTOs) which were identified through the systematically using a selection process.

The present study examines and understands the working mechanisms of Technology Transfer offices at the pan-India level and includes TTO features, administration, bottlenecks, strengths, learnings, governance, capacity-building needs, and challenges to implement Technology Transfer procedures in the country.

The study included both a national and an international component. In the national part, diverse institutions, such as central universities, laboratories under CSIR, ICAR, institutions of national importance like IITs, NITs, public and private state universities were included in the study. At the pan-India level, the 'as-is' status of TTOs was analysed using a variety of research instruments, including a characterization matrix and a questionnaire (Parts A and B). During the secondary research and in-person investigation both quantitative and qualitative factors were considered to generate a comprehensive framework. In the international part, the innovation and Technology Transfer ecosystems of developed countries like Germany, Israel, Switzerland, South Korea, and the United States of America (USA) were studied and analysed.

This research aimed to improve TTOs and the Technology Transfer process in India by examining their structure and functions, administrative processes and governance frameworks, capacity-building needs, and challenges. The project aims to generate evidence-based recommendations and best practices framework to help TTOs grow and develop, making the transfer of knowledge and technology from academic and research institutions to the commercial sector more efficient and effective. The findings of the study can be utilized for the capacity development or providing other supports to the TTOs, as well as the consolidation and standardization of India's ecosystem for Technology Transfer.

Kashmir Singh

Prof. Kashmir Singh

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Contents

Abbreviations and Acronyms

AGNII	Accelerating Growth of New India's Innovations
AMT	Advanced Manufacturing Technologies
ARAI	Automotive Research Association of India
BDTD	Biomedical Device and Technology Development Program
BEE	Bureau of Energy Efficiency, Ministry of Power
BIPP	Biotechnology Industry Partnership Programme
BIRAC	Biotechnology Industry Research Assistance Council
CPR	Centre for Policy Research
CRADAs	Cooperative Research and Development Agreements
CTI	Commission for Technology and Innovation
CNSE	College of Nanoscale Science and Engineering
DAE	Department of Posts and Department of Atomic Energy
DBT	Department of Biotechnology
DDP	Device Development Programme
DIO	Defence Innovation Organisation
DPIIT	Department for Promotion of Industry and Internal Trade
DSIR	Department of Scientific and Industrial Research
DST	Department of Science & Technology
DoS	Department of Space
DoT	Department of Telecommunications
DSIR	Department of Scientific and Industrial Research
EXIST	Existenzgründungenaus der Wissenschaft
EAER	Economic Affairs, Education, and Research
ECSEL	European projects in the field of electronics
EPFL	Ecole Polytechnique Federale de Lausanne
FDI	Foreign Direct Investment
FICCI	Federation of Indian Chambers of Commerce and Industry
FLCTD	Facility for Low Carbon Technology Deployment
GDP	Gross domestic product
GERD	Gross domestic expenditure on research and experimental development
GITA	Global Innovation and Technology Alliance
GII	Global Innovation Index
GoI	Government of India
HEI	Higher Education Institution
HTGF	High-Tech Gründerfonds
I-A	Industry-Academia
ICAR	Indian Council of Agricultural Research
iDEX	Innovation for Defence Excellence
IFCPAR	Indo-French Centre for Promotion of Advanced Research

IP	Intellectual Property
IPRs	Intellectual Property Rights
ITTN	Israel Tech Transfer Organization
ITTP	International Technology Transfer Programme
IUSSTF	Indo-US Science & Technology Forum
KETEP	Korea Institute of Energy Technology Evaluation and Planning
KIAT	Korean Institute for Advancement of Technology
KISTEP	Korea Institute of S&T Evaluation and Planning
MeitY	Ministry of Electronicsand Information Technology
MoES	Ministry of Earth Sciences
NAAC	National Assessment and Accreditation Council
NAMII	National Additive Manufacturing Innovation Institute
NIDHI	National Initiative for Developing and Harnessing Innovations
NSTC	National Research Council for Science and Technology
NMITLI	New Millennium Indian Technology Leadership Initiative
NRL	National Research Laboratory
NSTEDB	National Science & Technology Entrepreneurship Development Board
NSTMIS	National Science & Technology Management Information System
OECD	Organization for Economic Cooperation and Development
PACE	Promoting Academic Research Conversion to Enterprise
PACER	Polar Science and Cryosphere Research
PM-STIAC	The Prime Minister's Science, Technology and Innovation Advisory Council
PPP	Public Private Partnerships
PTT	Private Technology Transfer
PU	Panjab University
PMU	Project Management Unit
PSI	Paul Scherrer Institute
SBIRI	Small Business Innovation Research Initiative
SNI	Swiss Network for Innovation
SPR	Scientific Policy Resolution
SIROs	Scientific and Industrial Research Organizations
SERI	State Secretariat for Education, Research and Innovation
SNU	Seoul National University
STI	Science, Technology, and Innovation
STIO	Science and Technology Innovation Office of South Korea
STIP	Science Technology Innovation Policy
SWOT	Strengths, Weaknesses, Opportunities and Threats

TADF	Technology Acquisition and Development Fund
TCEs	Technology Commercialization Entities
TCO	Technology Commercialization Office
TCOEs	Telecom Centres of Excellence
TEDO	Technology Exports Development Organisations
TISC	Technology and Innovation Support Center
TPEM	Technology Platform for Electric Mobility
TRA	Textile Research Associations
TRL	Technology Readiness Level
TT	Technology Transfer
TTC	Technology Transfer Centre
TTO	Technology Transfer Office
UNIDO	United Nations Industrial Development Organization
U.S.A.	United States of America
USI	Universita della Svizzera Italiana
WIPO	World Intellectual Property Organization
WMT	Waste Management Technologies

Definitions

TT: Technology Transfer	Transferring knowledge or expertise related to some aspect of technology from one user to another (Cormican and Connor, 2009).
TTO: Technology Transfer Office	A Technology Transfer Office (TTO) is a specialized department within academic institutions, research organizations, or corporations responsible for managing technology and knowledge transfer from research and development activities to practical applications in the market.
TCO: Technology Commercialization Office	A Technology Commercialization Office (TCO) is a department or entity within an organization, often associated with research institutions, universities, or corporations, focused on converting innovative technologies and research outcomes into viable commercial products, services, or applications.
TTC: Technology Transfer Centre	A Technology Transfer Centre (TTC) is a specialized organization, often associated with research institutions, universities, or governmental bodies, that serves as a hub for facilitating the transfer of technology and knowledge between academia, research, and industry sectors. The primary focus of a Technology Transfer Centre is to bridge the gap between research outcomes and practical applications, contributing to economic growth and innovation.
Technology Producers	The creators of the technology as a product or process comprise the contributors from any public or private organisations or any individual innovator.
Resource Providers	Agencies that provide resource support in the form of intellectual resources, human resources and infrastructural resources will also be considered.
Funding Agencies	Any funding agency (public or private) which provides financial support to develop and exploit the technology.
Governance Practices	The practices that focus on governance of the Technology Transfer process at the legislative (Laws/Acts/Policies) and administrative levels for Technology Transfer (Guidelines) are implemented at the national and institutional levels.
Organizational and	This attribute focuses on the TTO organizational structure, leadership and

Managerial Practices	management, team composition, intellectual property management, technology evaluation and valuation practices.
Financial Sources and Administration Practices	This attribute focuses on sourcing financial capital for Technology Transfer activity and adequate financial governance and administration of the Technology Transfer at the institute level.
Functional Practices	The functional practices focus on critical functions that the Technology Transfer office caters to, such as protection of the Institute's Intellectual Property (IP), IP marketing, technology assessment and valuation, technology transfer and commercialization of the technologies developed.
Output/Reporting Practices	Proper output reporting system of the Technology Transfer entity.
Linkage and Network-oriented Practices	These practices focus on the importance of system interconnectedness in the Technology Transfer ecosystem before and after the Technology Transfer. It also becomes imperative for a Technology Transfer Office to develop various linkages and undertake networking for effective Technology Transfer from knowledge-based institutions to the market.
Incentivizing Practices	The incentivizing practices to motivate faculty/scientists/researchers to commercialize technology at the institutional level. On the other hand, incentivization mechanisms should attract the industry to take up technologies developed by academic and research institutes.

Tables

Figures

Executive Summary

In 2016, the Bureau of Energy Efficiency, Ministry of Power, and UNIDO jointly launched the Facility for Low Carbon Technology Deployment (FLCTD), a 10-year GEF-funded project, to facilitate the deployment and scaling of innovative low-carbon technologies in India. The project aims to promote innovation in clean and efficient energy technologies for industrial and commercial sectors and address technology gaps to reduce greenhouse gas (GHG) emissions.

Once scaled up, these innovative low-carbon technologies are expected to become the leading solutions to mitigate climate change. The FLCTD project has been working with the stakeholders and providing specific capacity-building support to strengthen the clean technology innovation ecosystem comprising knowledge-based institutions, industry, government and other end-users.

Many public-funded research organisations and academic institutions report intellectual property related to low-carbon technologies, which is being incentivized through various entrepreneurship development initiatives and support from incubators and other forms of industry-academia interface. However, over the years, only a handful of the total clean/low-carbon technologies supported by the FLCTD project have directly come from technical institutes or laboratories. This indicates critical gaps in the existing technology transfer and commercialization systems.

Studies independently carried out by the Department of Science and Technology- Centre for Policy Research (DST-CPR) and Department of Scientific and Industrial Research (DSIR) have highlighted the need to strengthen the industry-academia relations for more substantial technology transfer and commercialization engagements in the country. Thus, there is a need to identify and address the factors that inhibit technology transfer from laboratories to private enterprises.

As part of a targeted approach to identify and assess technology transfer centres in higher education institutions and laboratories and to undertake a comparative assessment of international best practices in technology transfer and industry–academia collaboration, the Department of Science and Technology's Centre for Policy Research based at Panjab University, Chandigarh partnered with UNIDO, under FLCTD project to identify the critical gaps and challenges faced by the Technology Transfer Centres (TTC) / Technology Transfer Offices (TTO) in (a) public and private technical institutes/universities, and (b) private and public laboratories and research facilities.

This study provides an "as-is" account of the structural and operational practices, bottlenecks and the challenges faced by Indian TTCs/TTOs. It is based on the information collected through desk research and qualitative and quantitative data from field visits and meetings with 25 TTOs nationwide. The report further provides a good practices framework from five international ecosystems vis-à-vis the United States of America, Switzerland, Germany, Israel and South Korea, and from studying the Indian ecosystem.

The present project report is organized into five chapters and provides detailed background, methodology and findings of mapping and characterization of the Indian Technology Transfer ecosystem. Each chapter has been divided into sections and sub-sections to enhance the readability.

The **First chapter** of the report briefly introduces BEE, UNIDO, FLCTD project and DST-CPR. It sets the context of studying the technology transfer ecosystem by highlighting its critical enabling role and importance in the technology commercialization process.

The **Second chapter** details the overall study approach and delves into the study background, scope and limitations. It is important to note that this work has been designed and treated as a "backgrounder".

It provides the "as-is" account of the current Indian technology transfer ecosystem in higher education institutes and national research laboratories. It is not an attempt to analyse, evaluate, or rank the performance of TTOs.

The **Third chapter** provides detailed insights into the methodology adopted to complete the work. Given this work's important nature and scope, the selection of institutes, shortlisting, design and development of the research instruments, questionnaires and data handling were developed based on methodology presented in internationally recognized manuals. Desk research of the information available in the public domain and reputed international peer-reviewed journals were referred to at various stages of the work.

The **Fourth chapter** provides the findings and observations based on the desk research and the primary data collected during the in-person visits and discussions at the select 25 TTOs. The practitioners of TTOs have developed diverse mechanisms for establishing, functioning and monitoring in the absence of an apex-level guiding framework. These observations provide strong indicators to formulate a hypothesis for future in-depth studies to analyze and understand each aspect of the TT ecosystem in the country. The good practices from international TT ecosystems and current Indian TT practices are also presented in this chapter.

The **Fifth chapter** presents a list of recommendations based on the findings of this study. It puts forward a case for further steps to strengthen the country's Technology transfer and commercialization ecosystem. Information related to the selection and shortlisting of the TTOs, research instruments, attributes chosen for the study, characterization matrix, questionnaires, analysis and innovation systems of each of the five countries studied under this work is provided separately in Annexures as supplementary material to the main report. An overview of the Indian innovation ecosystem and the five international ecosystems is also included.

Findings from this study are expected to provide the Department of Science and Technology, Bureau of Energy Efficiency, Centre for Policy Research (Panjab University), and UNIDO with the necessary relevant information to determine specific interventions to strengthen the technology innovation ecosystem. The findings and recommendations can be drawn to focus on enhancing India's cleantech/low-carbon innovation ecosystem.

Geographical presence of TTOs' host institution

INTRODUCTION

1. Introduction

Chapter 1 introduces the study and briefly introduces the organizations leading this work. In the later part of the chapter, the relevance of Technology Transfer in enabling the commercialization of ideas and innovations has been highlighted. Section 1.1 introduces UNIDO, BEE and the Facility for Low Carbon Technology Deployment project. Section 1.2 of this chapter briefly overviews the country's STI ecosystem. A current model of Technology Transfer focussing on licensing and increasing adoption of innovation has been presented in Section 1.3. The relevance of Technology Transfer and its importance has been highlighted in section 1.4.

1.1 Background

The United Nations Industrial Development Organization (UNIDO) promotes inclusive and sustainable industrial development (ISID) to assist industries of developing countries and economies in transition. In India, UNIDO has extensively cooperated with government agencies to develop policies and institutional frameworks to support entrepreneurship development and has strong partnerships with various industrial and enterprise associations. Since 2011, UNIDO, with the support of the Global Environmental Facility (GEF), has successfully implemented cleantech innovation projects in many partner countries, including India.

In 2016, the Bureau of Energy Efficiency, Ministry of Power, and UNIDO jointly launched the Facility for Low Carbon Technology Deployment (FLCTD), a 10-year project to facilitate the deployment and scaling of innovative low-carbon technologies in India. Funded by the GEF. The project aims to promote innovation in clean and efficient energy technologies for industrial and commercial sectors and address technology gaps to reduce greenhouse gas (GHG) emissions. These innovative low-carbon technologies, once scaled up, are expected to be the main solutions to mitigate climate change. Over a hundred innovations have been selected under the project for mentoring and technology validation support.

The Bureau of Energy Efficiency (BEE) drives policy development under the Ministry of Power, Government of India (GoI). It implements strategies and programmes to achieve efficient end-use of energy across the sectors of India's economy. In the Paris Climate Agreement, the Government of India has communicated that its Nationally Determined Contribution is to reduce the emissions intensity of its Gross Domestic Product (GDP) by 33 to 35 per cent, updated in 2022 to 45 per cent, by 2030 from the 2005 level. The BEE, created under the Energy Conservation Act 2001, is primarily responsible for reducing the energy intensity of the Indian economy. The Bureau of Energy Efficiency (BEE) estimates untapped potential in the industrial, commercial, and agricultural sectors.

The FLCTD project aims to link the critical connections between the stakeholders and provide specific capacity-building support to strengthen the clean technology innovation ecosystem comprising knowledge-based institutions, industry, government and other end-users.

The FLCTD project's implementation is divided into two main components:

Component I – Innovation Ecosystem for selecting technology innovators and instituting competitive awards and policy incentives. Aimed at providing mentoring and technology validation support to technology innovators and their innovations that are at the pre-commercial stage of development. The innovation challenge is implemented by BEE and UNIDO, jointly with the help of a panel of experts, who are involved in defining the innovation challenge for different technology verticals and choosing the winners through a rigorous screening and selection process. The innovation challenge winners receive financial support from FLCTD to validate the efficacy of the innovations

Component II - Technical assistance for Technology Transfer Support Facility – It aims to strengthen the innovation eco-system (system of innovation), particularly for climate-friendly technologies, by providing appropriate need-based technical assistance/facilitation to the Technology Transfer Office (TTO)/ Technology Commercialization Office (TCO)/ Technology Transfer Centre (TTC) in the country. The objective is to establish a deployment support ecosystem for Science and Technology (S&T) based innovative climate mitigation technologies. This is to be accomplished by:

- Identification of appropriate networks and centres for research and deployment of low-carbon technologies and their verification.
- Facilitation of knowledge exchange through consultations/workshops with national/ international experts, documentation and dissemination of the information and
- By developing specific interventions.

Many public funded research organizations and academic institutions report intellectual property related to low-carbon technologies, and innovation is being incentivized through various entrepreneurship development initiatives, incubators and other forms of industry-academia interface. However, only a handful of the total clean/low carbon technologies supported by the FLCTD project have directly come from technical institutes or laboratories. This indicates critical gaps in the existing technology transfer and commercialization systems.

Studies independently carried by the Department of Science and Technology- Centre for Policy Research (DST-CPR) and Department of Scientific and Industrial Research (DSIR) have found that:

- Though there are several government programs and organizations to support technology commercialization activities in the country, a framework for defining the problem statement, incubation, acceleration, and validation support has not been specified.
- Institutes do not have an outreach platform to promote their research work. Innovators are expected to find and execute innovation commercialization activities of their research. Experts agree that Technology transfer is a specialist area of its own and requires skilled inter-disciplinary human resources for successful execution.
- Industry-academia interaction is limited to one party doing the research – the other doing the commercialization. Co-creation, co-research and co-commercialization have not yet been realized.

Hence, there is a need to identify and address the factors that inhibit technology transfer from laboratories to private enterprises. A targeted approach is required to identify and assess technology transfer centres in institutions and laboratories and to undertake a comparative assessment of international best practices in technology transfer and industry–academia collaboration.

With the above background, the Department of Science's Centre for Policy Research based at Panjab University, Chandigarh, was engaged by UNIDO under the FLCTD project to evaluate the current levels of collaboration and co-creation within the innovation ecosystem in India and identify the critical gaps and challenges faced by the Technology Transfer Centres / Technology Transfer Offices in:

- Public and private technical institutes/universities.
- Public and private laboratories and research facilities, as compared to peers in select developed countries.

Findings from this study, presented in the Chapters that follow, are expected to provide the Department of Science and Technology, Centre for Policy Research (Panjab University), and UNIDO the necessary information to determine specific interventions to strengthen the technology innovation ecosystem and propose models to support the cleantech innovation ecosystem in India.

1.2 Science, Technology and Innovation Ecosystem in India

Science, Technology and Innovation (STI) Ecosystem is the convergence of Science and Technology (S&T) that inspires ideas to nurture and hence mushroom innovation. Earlier, Science was considered a broad domain (Sattiraju,2022), while Technology and Innovation were considered a part of it (Meyer, 2002). Later, Science was identified as one of the components of Innovation and together, Science and Technology help to strengthen the innovation ecosystem (Figure 1). S&T-based innovations help to develop strategies to capitalize on the R&D ecosystem explicitly. Investment made in STI is essential for a nation's economic development and social progress, and it is pivotal to meet the ambitions to become an innovation-driven economy. India now ranks 40th among the 132 economies worldwide, per the Global Innovation Index (GII), 2022. Globally, it has ranked 42nd in innovation inputs while 39th in innovation outputs.

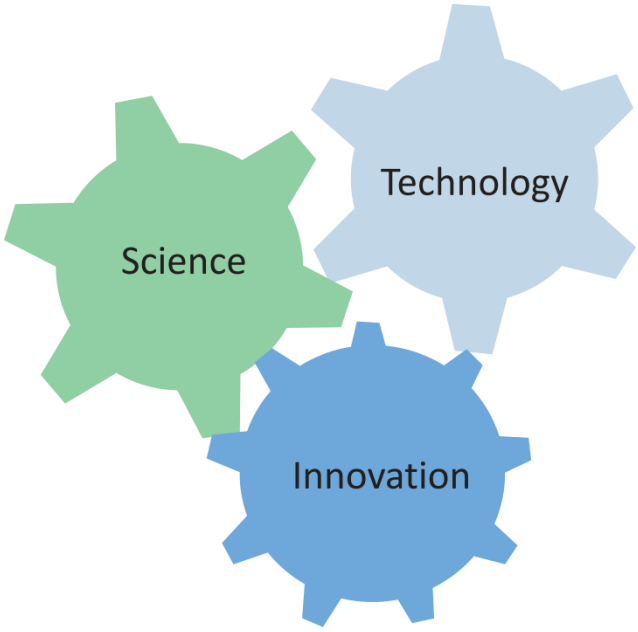

Figure 1: Fusion of Science, Technology and Innovation (STI)

As per the National S&T Management Information System (NSTMIS) Report on R&D Statistics by the Department of Science and Technology (DST), India has raised its innovation capabilities in terms of the increase in the number of patent applications, but few of them reached to the stage of Technology Commercialization. However, programmes like 'Mission Innovation', a global initiative launched as a part of the Paris Agreement 2015 to catalyse and stimulate R&D investments and take respective actions for the demonstration of affordable, clean energy-directed and accessible technologies in the decade to come to direct countries' efforts towards net zero.

To strengthen the Technology Transfer and technology commercialization ecosystem, India plans to announce its 5th National STI policy with prominent features such as:

- Creation of equitable and accessible STIs.
- Strengthen STI capacity.
- Supporting technology indigenization.
- Reinforcement of entrepreneurship and innovation.
- Promotion of equity and inclusion.
- Streamlining science communication and public engagement.
- Strengthening India's S&T engagements and overall STI governance.

1.3 Technology Transfer

Technology Transfer (TT) can be understood as transferring knowledge or expertise related to some aspect of technology from one user to another (Cormican and O'Connor, 2009). It prominently involves streaming outcomes from scientific and technological research to the marketplace and broader society, along with associated skills and procedures. It is an intrinsic part of the technical innovation process. Primarily, it can be pursued formally or informally (OTA, 1982).

A Formal mode of TT is a channelized process with activities to facilitate the appropriate application of the technology, such as technology valuation, assessment, evaluation of Technology Readiness Level, and Intellectual Property exchange. The informal mode of TT is a non-channelized process that involves informal channels such as individual interlinkages and indirect approaches for TT negotiation.
One TT process given by Ravi & Janodia (2022) is presented in figure 2 below, covering 07 key steps of TT as described below

1. **Research and Development:** This step involves problem identification, selection of the aligning technology and presenting a potential solution. The output of this step is a culmination of laboratory work as innovation and the development of a prototype.

2. **Technological Development:** Technology Development focuses on sufficiently increasing the maturity level of the technology so that reliable solutions can be designed to address specific problems.

3. **Technology assessment:** The steps involve the assessment of the potential of technology through Technology Readiness Level (TRL) assessment.

4. **Market assessment:** This step involves the valuation of technologies, potential solutions they can offer, and the economic analysis based on market research (including the demand for technology and identification of potential licensees).

5. **Commercial viability:** This step focuses on determining the commercial viability of the proposed technology as a platform or technological solutions being developed.

6. **Technology Transfer Agreement:** The technology transfer agreements cover different aspects of the engagement. such an agreement covers (is not limited to) the terms of the license granted (may be exclusive or non-exclusive) based on the technology, payment options (royalty, milestone, or agreed mechanism of benefit sharing), data sharing, troubleshooting and agreements on future R&D and access to the new knowledge/technology being generated.

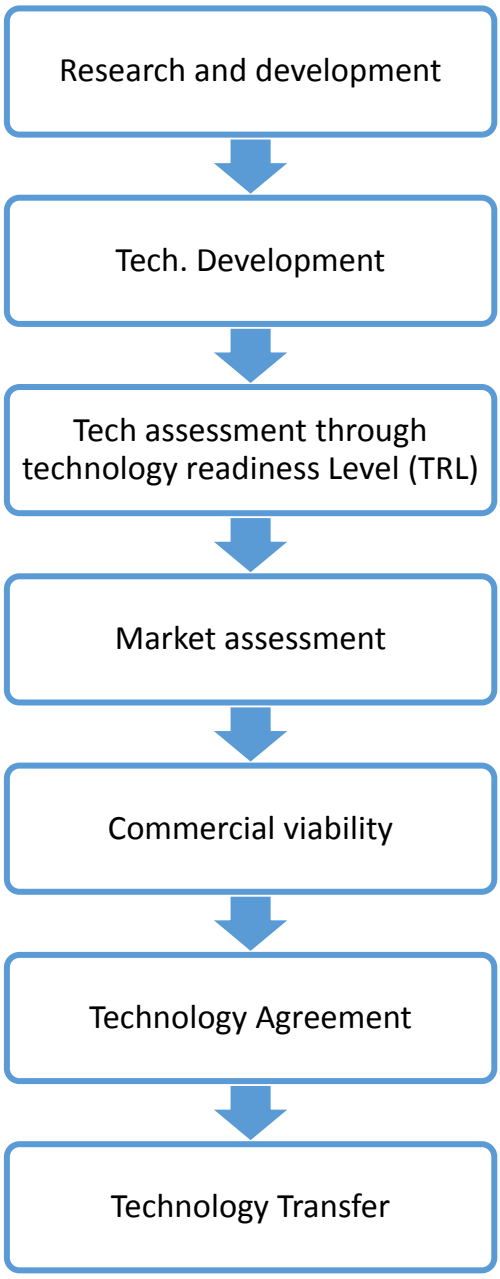

Figure 2: TT process by Ravi & Janodia (2022)

Additionally, few other prominent models found in literature for Technology Transfer domain have been listed in the Annexure I (a). These models helped in nurturing the TT ecosystem of the country with time. To sustain the momentum, efforts are required to enhance the focus on the Technology Readiness Level (TRL) scale while assessing technology in India. Further, there is an increase in support for indigenous technologies to cover the transition between TRL 3 to TRL 7 and come out of the death valleys of Technology Transfer (TT).

1.4 Relevance of Technology Transfer

The function of Technology Transfer, in its different forms and modalities, supports all stages of technology commercialization. As an essential component of an innovation ecosystem, it promotes collaboration to move scientific findings, knowledge and intellectual property from creators, such as universities and research institutions, to public and private users to create new products and services. It formalizes the engagement of different stakeholders at different stages of technology development and commercialization – thus clearly marking the expectations, roles and responsibilities.

The universities and research institutions need to connect with government, policy, industry and research institutions in a way that each brings their resources and expertise together. This collaborative environment pushes the development of the overall innovation ecosystem in the region/sector by accelerating breakthroughs in emerging technologies, improving market competitiveness, and driving economic growth. Additionally, TT encourages entrepreneurship and public-private partnerships, thus enabling the commercialization of ideas and innovations that would have otherwise remained undeveloped. This contributes to sustainable development through job creation, increased productivity, and improved living standards through better products and services.

STUDY APPROACH

2. Study Approach

Chapter 2 presents a comprehensive overall approach taken by the DST-CPR to conduct this study. The Section 2.1 provides a Background of the study and the overall scope of the work has been defined in the Section 2.2. It also presents a list of vital steps involved in the study process. Section 2.3 provides a list of limitation of this work and strongly recommends against overdrawing the findings of this work. This study has been designed as an "as-is" assessment of the current Indian TT ecosystem and does not investigate any correlations or causations. The sequential workflow of the study has been presented in the section 2.4.

2.1 Background

Several public funded research organizations and academic institutions are reporting Intellectual Property (IP) related to low-carbon technologies, and innovation is being incentivized through various entrepreneurship development initiatives, incubators and other forms of industry-academia interface. However, only a handful of the total low-carbon technologies supported by the FLCTD project have come directly from technical institutes or laboratories. This indicates critical gaps in the existing TT and commercialization systems.

Separate studies independently conducted by the Department of Science and Technology- Centre for Policy Research (DST-CPR) at Panjab University (PU) and the Department of Scientific and Industrial Research (DSIR) have also suggested strengthening the TT and commercialization functions through relevant capacity building and training. Thus, there is a need to identify and address the factors that inhibit Technology Transfer from laboratories to enterprises. A targeted approach is required to identify and assess TTOs in institutions and laboratories and to undertake a comparative assessment of international best practices in Technology Transfer and Industry–Academia collaboration.

Findings from this study shall offer UNIDO and the DST-CPR, PU, the necessary information to determine specific interventions to strengthen the technology innovation ecosystem in India.

2.2 Scope of the Study

The study undertakes activities relating to identifying and appraising the prominent existing TTOs. It aims to identify the initiatives these TTOs are part of and the mechanisms through which they provide technology development and transfer support. A targeted approach has been followed that identifies and studies the TTOs in institutions and laboratories. The study identifies the key factors and gaps that inhibit Technology Transfer from laboratories to private enterprises in India. Best practices from select international innovation ecosystems have been compiled for a comparative assessment.
The following are the objectives of the study.

- To identify the current activities of Technology Transfer within the innovation ecosystem in India.
- To identify critical gaps and challenges faced by the TTOs in Indian HEIs (Higher Education Institutions) and NRLs (National Research Laboratories) compared to their peers in select developed countries.

- To provide findings and a way forward to the Component II of the FLCTD project on specific intervention to build the capacity of TTOs in India for enhancing the commercialization of innovations.

The critical steps covered during the course of this study are as follows:

- Prepare a long list to include all the institutions and research organizations in India working on research and innovation and having a Technology Transfer Office (TTO).
- Development of short-listing criteria to identify TTOs in India based upon the indicators identified from the literature review covering different aspects of TT and select 30 TTOs across India.
- Selection of five international innovation ecosystems based on the innovation ranking of countries from the Global Innovation Index (GII), 2022, to understand the International TT ecosystem based on their detailed list of specific ecosystem players and roles in their respective geographies.
- Lists the best practicess based on analysing five international innovation ecosystems.
- Development of a characterisation matrix to analyse the 'as-is' status of the shortlisted TTOs based on inputs from steps 2 and 4.
- Identify the points of divergence as compared nationally and to the international ecosystems by taking inputs from the research findings.
- Structuring best practice framework for the TT ecosystem in the Indian context.
- Selection of the ten potential TTOs in India for further capacity-building support.
- Preparation of recommendations for building the Technology Transfer capacity of the identified TTOs in step 8.

2.3 Limitations

Within the scope of the FLCTD project, this study is designed as a ‘backgrounder’ to identify the current ‘as-is’ practices of the technology transfer operations in the country. While this study provides a comprehensive introduction to the current TT practices in the country and compares the Indian ecosystem with the TT ecosystem of 5 more developed countries, more research is required to achieve a deeper understanding of the Technology Transfer ecosystem in the country.
Researchers referring to this work must make a note of the following:

- The study cites the as-is status of the TT ecosystem in India based on one-to-one interactions with the select Indian TTOs.
- The study does not cover the alignment or competitive study of the TTOs or analyse the activities of the TTOs. It does not measure the efficiency of the TTOs.
- The study does not compare the specific international TTOs with the national TTOs.
- This does not focus on any specific sectoral area.
- This study only highlights the best practices of the national and international TT ecosystem based on the information available in the public domain.
- This study covers Technology transfer practices only in HEIs and NRLs (CSIR and ICAR) and does not cover TT practices in other organizations, PSUs and industry

2.4 The layout of the study

A sequential workflow for the detailed study of national TTOs to increase innovation commercialization is presented in Figure 3. The plan incorporates the project's objectives and critical steps mentioned in section 2.2 by sequentially representing the various phases. The study was carried out in stages: Phases I, II, III and IV. Phase I caters to the initial research. Phase II is dedicated to the development of research instruments. Phase III aligns towards data collection. Phase IV puts out the outcomes of this study.

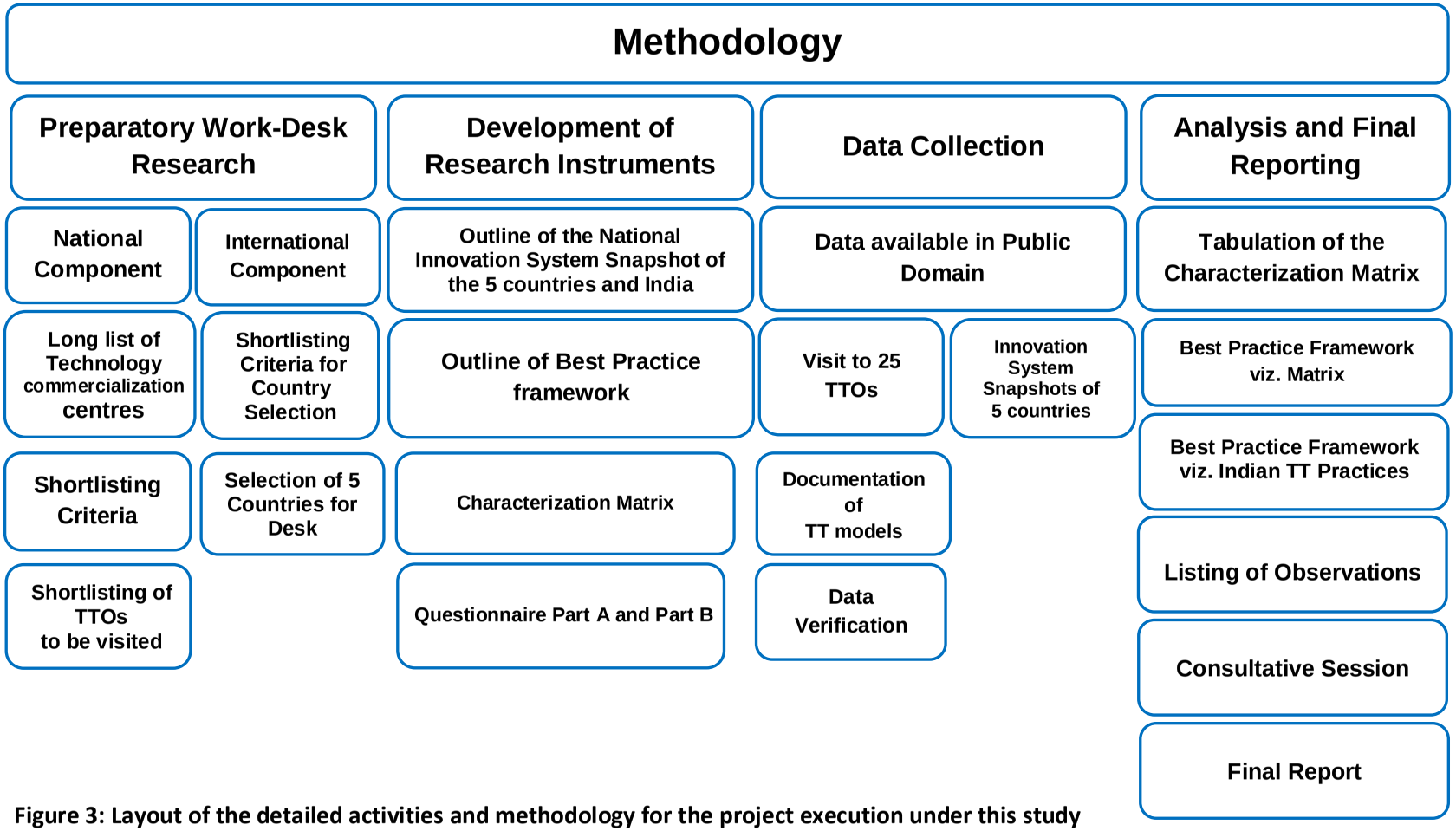

Figure 3: Layout of the detailed activities and methodology for the project execution under this study

METHODOLOGY AND DATA PROCESSING

3. Methodology and Data processing

Chapter 3 describes the methodology adopted for this study. It explains in detail the process of updating of long list prepared with new additions of Higher Education Institutions (HEIs) and National Research Laboratories (NRLs). Chapter highlights the shortlisting of 25 institutions with active Technology Transfer activities based on 3-point shortlisting criteria developed in this study based on key TT indicators. Chapter describes the selection of five international TT ecosystem that were screened based on a shortlisting criteria. It describes the best practicess of International Innovation Ecosystems and their integration in national TTO study. Chapter includes the indicators to study the National as well as International TTO ecosystem that led to the development of a characterization matrix. As well as brief out development of research instruments used to conduct this study and the SWOT analysis conducted to understand TT ecosystem at institutional level.

3.1 Preparation of the long list of TTOs in the Indian academic institutions & NRL

The initial long list papered jointly by the Programme Management Unit (PMU), UNIDO-FLCTD and DST-CPR, PU was updated with new additions. Higher Education Institutions (HEIs) and National Research Laboratories (NRLs), which mentioned having a Technology Transfer function were added to the updated list. Information was taken from the public domain, such as the official websites of the respective institute/university/organization.
The final long list of 524 institutions (Annexure-I (b)) had a representation of:

- Institutions of National Importance (INIs) such as Indian Institutes of Technology (IITs), Indian Institutes of Science Education and Research (IISERs), and National Institutes of Technology (NITs).
- Central & State (public & private) universities.
- NRLs funded by major organizations such as the Council of Scientific and Industrial Research (CSIR), New Delhi, Department of Science and Technology (DST), New Delhi, Department of Biotechnology (DBT), New Delhi.

The list was screened for the shortlisting of institutions with active Technology Transfer activities. Based on 3-point shortlisting criteria, 59 such institutions were identified, listed in Annexure I (c) (List of the 59 institutes identified after initial screening). The HEI and NRL category distribution of 59 HEIs/NRLs is depicted in Annexure I (d).

3.2 Development of the shortlisting criteria to TTOs/TCOs for the study under context

A short-listing criterion to identify TTOs in India was developed based on the following:

1. A set of indicators was selected from literature (research publications, innovation-linked reports; Science, Technology and Innovation (STI) related research papers, reports and manuals such as the GII Report, Report on Evaluation of Innovation Excellence Indicators of Public-Funded R&D Organizations Report by PSA, GoI; World Intellectual Property Indicators, WIPO; Frascati Manual, Oslo Manual, etc.) that focuses on Technology Transfer along with the specific case studies on the same. Thus covering different aspects of TT.

2. TTO attributes for the shortlisting criteria were checked for shortlisting of the TTOs. The outline shortlisting criteria was based on three parameters mentioned in Table 1.

Table 1: The shortlisting criteria for selecting TTOs at the national level

Indicators	Brief description
TTO Function	TT as main activity: The institutions were selected for performing Technology Transfer as the main activities being taken care of by the host institution's dedicated cell/centre/unit/office.
Functional Attribute of TTO	Undertaking IP and TT commercialization activities: Institutions were screened for the functional attributes of TTO, such as intellectual property filing, technology development, and commercialization.
Organizational Structure of TTO	Dedicated manpower for TT operation: The structure of the TT unit was screened for the presence of a dedicated team and Team Leader.

A total of 25 TTOs were screened, listed in Annexure I (e), based on shortlisting criteria mentioned in Table 1. The category distribution of 25 HEIs/NRLs is depicted in Table 2.

Table 2: The category distribution of the 25 shortlisted HEIs/NRLs

Categories of Institutes	Numbers (Total: 25)	Categories of Institutes	Numbers (Total: 25)
IIT	7	DBT-LAB	1
IISc	1	State University	1
IISER	1	Central University	3
NIT	1	Pvt - HEI	4
ICAR	1	CSIR-LAB	5

3.3 Selection of Five International Innovation Systems

The international innovation systems were analysed to draw input on how international innovation systems work in the Technology Transfer sphere and outline global best practices around the same. The criterion for selecting five International Innovation systems was based on countries ranking in the GII 2022. The top innovation-ranked countries from across the region and income groups were identified. The selection criteria used for selecting five international innovation ecosystems is presented in Table 3.

Table 3: The selection criteria for the international innovation ecosystem

Sr. No.	Selection Criteria
1.	Top innovation-ranked countries as per **regional representation** (including regions: North America, Europe; Northern Africa and Western Asia, and Southeast Asia, keeping in mind the high innovation growth in these regions.
2.	As per the regional representation, the top innovation-ranked countries were further **screened for their overall GII ranking and income group.** Considering that India aspires to transition from the lower middle-income group to the upper-middle-income group. The upper-middle-income countries were selected based on the highest innovation ranking in that category.
3.	The shortlisting criteria were focused on **selecting countries that rank above India** because the study aims to develop a best practice framework out of the international innovation ecosystem that can be adapted in India. The low-income countries were not considered in the study.

Based on the selection criteria mentioned above in Table 3, Switzerland, USA, South Korea, Germany and Israel were selected for further study detailed in Annexure II. The critical innovation ranking profile of all selected countries is further showcased in Table 4.

Table 4: Five countries selected to study the international innovation & Technology Transfer ecosystem

Country	GII Ranking	GII Ranking in Regional Category	GII Ranking in Income Category
Switzerland	1	1 (Europe)	1 (High Income)
USA	2	1 (North America)	2 (High Income)
S. Korea	6	1 (South East Asia, East Asia, and Oceania)	6 (High Income)
Germany	8	5 (Europe)	8 (High Income)
Israel	16	1 (North Africa and West Asia)	15 (High Income)

Seven innovation ecosystem attributes were selected for studying these countries' innovation profile and TT ecosystem with a focus on the Technology Transfer function. These were based on the insights presented in the WIPO working paper titled "Developing Frameworks to Facilitate University-Industry Technology Transfer: A Checklist of Possible Actions," as well as research papers by Siegel et al. (2004, 2007, 2023) and the inputs from study on “Global STI models concerning public-private partnerships” by DST-CPR, Panjab University in 2020 (Tewari et al. 2020)” The seven attributes thus identified are listed as follows:

1. Governance Practices
2. Organizational and Managerial Practices
3. Financial Sourcing and Administration Practices
4. Functional Practices
5. Output /Reporting Practices
6. Linkages and Network-Oriented Practices
7. Incentivizing Practices

The key stakeholders for each of the five international ecosystems identified were classified into the following four categories:

1. **The government** sets the priorities and landscape for innovation.
2. **Industry** acts as a knowledge user-based actor that consumes the output of the STI base.
3. **Academia and research institutes** generate knowledge and form the STI base.
4. **Others include facilitative and enabling institutional mechanisms** for stimulating innovation in the country.

The innovation profile and snapshot of TT ecosystems of the selected countries are also described in detail in Annexure II.

3.4 Best practicess of International Innovation Ecosystems

A comprehensive framework of best practicess was developed based on the desk research of the international innovation ecosystems. This framework aligned with the national innovation system approach to identify the primary attributes associated with each country's innovation ecosystem. Based on the initial study of the innovation ecosystems in Switzerland, USA, Germany, South Korea, and Israel, several notable factors that significantly enhance their innovation and Technology Transfer ecosystems were identified. These key standout points include:

1. **Legislative and administrative frameworks supporting innovation:** These countries possess well-defined legislative and administrative frameworks that provide robust incentives for research and development (R&D) and innovation. An exemplary case is the introduction of the Bayh-Dole Act in the USA, which revolutionized industry-academia engagements and spurred the Technology Transfer ecosystem in the country.

2. **System interconnectedness among innovation actors:** There is a strong emphasis on establishing interconnectedness between key innovation actors, ranging from knowledge generators to knowledge consumers, as well as the role of emerging knowledge facilitators and intermediaries. In all five countries, it was observed that linkages between these actors are well-established. For instance, the USA has dedicated intermediaries and government programs that bridge knowledge generators and knowledge consumers, leading to a higher success rate in Technology Transfer.

The best practice framework is portrayed in Figure 4 and elaborated in Table 5.

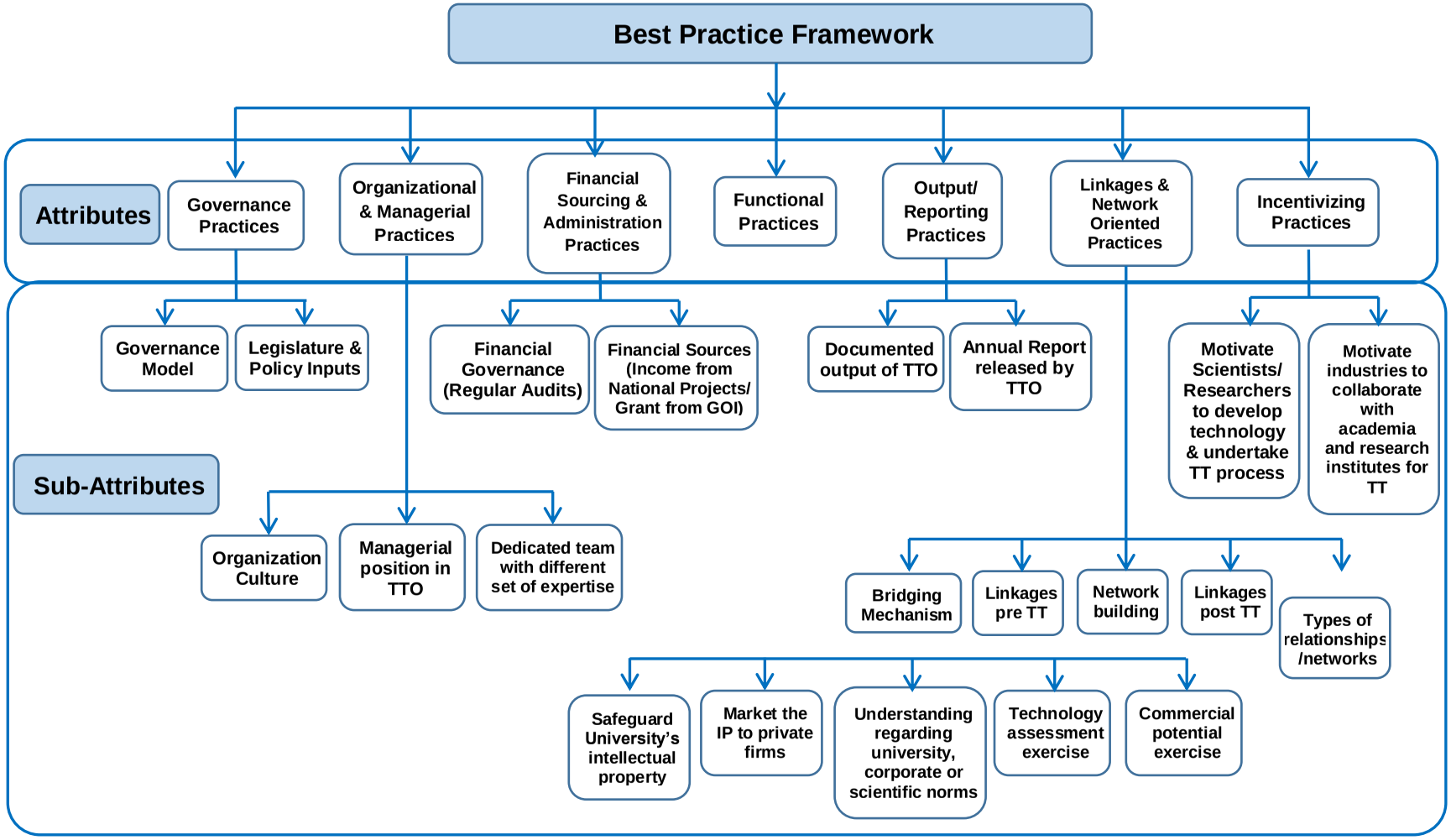

Figure 4: Best practices framework outline

Table 5: Detailed description of best practices framework attributes

Sr. No.	Attributes	Sub-Attributes
1.	Governance Practices	**Legislature and Policy Inputs:** • National level (National impetus on TT through Act/Law/Policy/Guidelines) • Institute level (Designing flexible institute policies on TT)
		Governance Model: Setting up a dedicated entity for TT (Technology Transfer) and sufficient resources devoted to Technology Transfer by the institute with flexible and efficient institute administrators
2.	Organizational and Managerial Practices	**Organization Culture:** • Impetus from the top leadership and organizational objectives focus on Technology Transfer • Organizational standards for promoting Technology Transfer • Technology Transfer is considered a source of revenue (via royalties, licensing fees, sponsored research agreements) • Organizations working to eliminate cultural and informal barriers that impede the TT process
		Managerial Position in TTO: The team leader and managerial position has to be there to lead the overall functioning of the TTO
		Dedicated Team with the following set of expertise: • Financial and market analysis • IP protection and management • Communication • Licensing
3.	Financial Sourcing and Administration Practices	**Financing Sources:** • Dedicated financial resources should be allocated to the TTO • The TTO should explore different routes for financial support, such as venture and angel funds, CSR, Alumni funds, etc.
		Financial governance: Regular audits (focus on technical audits)
4.	Functional Practices	**Safeguard the University's intellectual property:** Universities should be less aggressive in exercising IP rights and more open to licensing the technology rather than blocking it in IP form.
		Understanding regarding university, corporate or scientific norms and environment: • Technology assessment exercise • Technology Readiness Levels (TRLs) • Technology valuation • Commercial potential exercise • Technical specificities • IP ownership (type of IP licensing) • Negotiate Licensing agreements • Market the IP to private firms
5.	Output /Reporting Practices	**Documented Output of TTO:** Licences; Royalties; Patents; sponsored research agreements; start-up companies; invention disclosures; Students; informal transfer of know-how; Product development; Economic development

		Dedicated website/portal to display information Updation of the website/portal User-friendly portal to make matchmaking **Reporting in Annual Reports Annual Report released by TTO:** • Average Annual Licensing agreement • Average Annual Licensing Revenue
6.	**Linkages and Network-Oriented Practices**	**Bridging Mechanisms:** Effective interface /portal /technology display /exhibitions Types of relationship/networks • Personal relationships • TTO as a facilitator of relationships between scientists and firms • Knowledge transfer from industry to faculty members • Conference/expo/town hall meetings on TT issues • Contractual relationships
		Network building: Effective communication with stakeholders across the system and forging alliances between scientists and industry
		Linkages pre TT • Industry-academia connect • Entrepreneurship-scientist connect • Technology exhibitions and technology demonstrations
		Linkages post TT • Scientist/researcher continues involvement with the firm • Faculty members/scientists serve as technical advisors or on the board of directors for the firm (especially in the case of start-ups)
7.	**Incentivizing Practices**	**Motivate scientists /faculty /researchers to develop technology and undertake the TT process** • Royalty distribution formula (typically ranging from 25% to 50%) • Awards (recognition within the scientific community) • Promotional incentives
		Motivating industries to collaborate with academia and research institutes for TT • Financial and technical gain to the industry • Utilization of CSR funding for R&D

3.5 Integration of International Best practicess in National TTO Study

Based on the critical attributes identified for successful Technology Transfer, research instruments such as questionnaires and the characterization matrix were prepared for the national TTO study. The comparative analysis of the International and Indian Technology Transfer ecosystem addresses the following concerns:

- This approach aimed to comprehensively understand the distinct differentiations between the Indian innovation and Technology Transfer ecosystem and the selected international systems.
- Through this process, we were able to identify the critical gaps present in the Indian scenario and determine areas where we could draw insights from international best practices to address these gaps.

The inputs from the international best practice framework outline were incorporated for the national TTO study as follows:

- The characterization matrix and questionnaire, as presented in the following sections, covering all the critical attribute categories and subcategories as covered in the Best practicess framework specified in Table 5.
- The best practice framework was created for each selected country, referencing the best practice framework outline and incorporating notable examples marked as best practice catering to Technology Transfer.
- Inputs from national TTOs, obtained through research interviews and personal interactions, were categorized according to the best practice framework outline categories and subcategories.
- The collected data was compared with existing best practices in the selected countries, assessing their presence, absence, strengths, and weaknesses within the Indian context.
- Identifying the key areas where Indian TTOs diverge from the best practices in the more developed ecosystems will be instrumental in shaping the design of the operation model for Indian TTOs.

3.6 Development of a Characterization Matrix

To construct a comprehensive Characterization Matrix, various indicators and sub-indicators were selected through an extensive literature review of research papers such as Lafuente *et al.* (2019) and Frenkel A. *et al.* (2011), as well as reference manuals like the Oslo Manual (2018) and others. These indicators and sub-indicators were selected in alignment with the attributes and sub-attributes outlined in the best practices framework mentioned in section 3.4, which are listed below in Table 6.

Table 6: Detailed description of characterization matrix indicators with sub-indicators

Indicators	Sub-indicators
Features of TTO	• Full Name of the TTO • TTO age • Status of TTO • Legal Status
Functions within TTO	• Commercialization functions ○ Patents/technologies generation ○ Licenses/agreements for the technology transfer process • Research to analyze the market gap • Additional Activities pursued by TTO • Co-commercialization with other organizations
TTO Administration (Team/Staff)	• Number of full-time Employees • Number of part-time Employees • Team Leader
TTO Governance	• Governance Structure • Modes/Mechanisms for technology transfer • Average Time Taken for TT • Shelf life of Technology available
Policies/Agreements followed by TTO	• Agreements generally signed for technology transfer • Existence of dedicated policies/guidelines • Policy to describe the patent ownership • Policy for Incentive for TT • Policy for inbound technology transfer
Financial status of TTO	• Income from National Projects/ Grant from GOI
Linkages/Outreach	• Capacity Building ○ Workshop/Training/ Symposium/ Conferences related to TT ○ Technology Showcase/ Expo ○ Training and short courses attended by staff since 2015 (for capacity building/skill upgrade/career development) • Marketing/Promotion • Digital Portal • MoUs and other collaborating associations • Relationships with industries

The sub-indicators were further subdivided into numerous attributes to construct the Characterization Matrix which is detailed in Annexure I (f). Together, indicators, significators and attributes form 119 rows of the Characterization Matrix. Out of these 45 were taking alpha (Yes/No) values, 70 numeric values, and four alphanumeric values; to consider qualitative and quantitative aspects. These 119 rows formed the Y-axis of the Characterization Matrix. The X-axis of the Characterization Matrix contained the list of selected institutes with TTOs. Figure 5 depicts the layout of the Characterization Matrix.

X-axis

Y-axis

Attributes	TTO1	TTO2	TTO3	TTO4	TTOn
Features of TTO	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Functions within TTO	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
TTO Administration (Team/Staff)	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric
TTO Governance	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric
Policies/Agreements followed by TTO	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No
Financial status of TTO	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric	Alpha-Numeric
Linkages/Outreach	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Figure 5: Layout of Characterization Matrix (T_n=T_{25})

3.7 Data collection and Data handling

3.7.1 Research instruments

Based on the inputs required to populate the characterization matrix, a research instrument in a two-part questionnaire was drafted. The questionnaire was developed in line with the indicators, Sub-indicators and attributes of the characterization matrix, as mentioned in section 3.5. a two parts questionnaire was developed in Part A and Part B. Part A covers the quantitative questions, and Part B focuses on qualitative aspects of the study. The questionnaire responses were collected during in-person visits to the selected TTOs.

In addition, a SWOT analysis (Figure 6) was conducted to know the strengths, weakness, opportunities and threats of the shortlisted TTOs during in-person meetings. Participants scored the SWOT attributes of their TTO on a Likert scale of 1 to 5 with one being very low and five being very high. SWOT attributes were based on a literature survey (Maximova *et al.* 2021), is highlighted in Figure 6. These attributes in the form of questions were included in the Part B of the questionnaire. The questionnaire and an explanation of keywords used in the questionnaire are enclosed in Annexure I(g) (Research Instrument: Questionnaire (Part A and Part B)).

<table>
<tr><td> 
</td><td>OPPORTUNITIES
1. Young human capital capable of keeping pace with scientific and technological progress.
2. The ability to enter in new markets.
3. Collaboration among various stakeholders.
4. A promising local market for investments.
5. Opportunities for international cooperation.</td><td>THREATS
1. Attrition
2. slow pace of economic reform
3. slow pace of administrative reform
4. Slow development of education and training systems and curricula.
5. Lack of incentives for the private sector to invest in research.
6. Complex procedures for creating start-ups.</td></tr>
<tr><td>STRENGTHS
1. Trained TT personnel.
2. Networks.
3. Modern equipment/infrastructure.
4. Scientific sectoral approach
5. Financial and administrative independence</td><td>SO strategies: taking advantage of opportunities.
• Scientific sectoral approach.
• Young human capital capable of keeping pace with scientific and technological progress.</td><td>ST strategies: avoiding threats.
• Scientific sectoral approach.
• Lack of incentives for the private sector to invest in research.</td></tr>
<tr><td>WEAKNESSES
1. Strategic vision of the TTO
2. Income level of research workers
3. Technical expertise as per the local industries
4. Interest of private sector industries in research and technological development.
5. Relevant training & experience required for TTO function.</td><td>WO strategies: introducing new opportunities by reduction of weaknesses.
• Young human capital capable of keeping pace with scientific and technological progress.
• Relevant training & experience required for TTO function.</td><td>WT strategies: avoid threats by minimizing weaknesses
• Relevant training & experience required for TTO function.
• Brain drain and competence drain</td></tr>
<tr><td colspan="3">Score 1-5 (being very low and 5 being very high)</td></tr>
</table>

Figure 6: Layout of SWOT analysis matrix

The inputs of SWOT questions were further analyzed to better understand the functioning of the 25 TTOs covered in the study. SWOT responses taken as quantitative continuous data was used for this purpose which was in the form of percentage response of the Strengths, Weakness, Opportunities and Threats. A SWOT matrix was designed as shown in Figure 6 to analyse the various strategies to designate the TTOs as potential network partners.

3.7.2 In-person visits to TTOs for collecting field-based TT information at the PAN-India level

In-person visits were conducted to collect in-depth information about TT activities at 25 shortlisted TTOs through questionnaires. The meeting agenda of these meetings was as follows:

- Introduction to FLCTD project, accomplishments to date, future activities.
- Introduction to DST-CPR and activities of the Centre.
- Introduction to the institute's technology transfer office, covering the following:
    - Brief introduction, major accomplishments, key initiatives, technology transfer and technology commercialization activities of their respective institutions.
    - Major issues and challenges their respective teams faced while executing their assigned roles and responsibilities.
    - Suggestions related to specific interventions that could catalyse their activities.

The information gathered during the in-person interactions was recorded in the Part B questionnaire, which was compiled and shared with the TTOs for verification. Part A, which seeks primarily quantitative information, was also sent along with Part B at the verification stage. The process of data collection is depicted in Figure 7. A glimpse of these meetings is shown below in Annexure I (e). A thorough analysis of verified data was conducted to tabulate the Technology Transfer process, constraints encountered by TTOs, TT process gaps, and capacity-building needs.

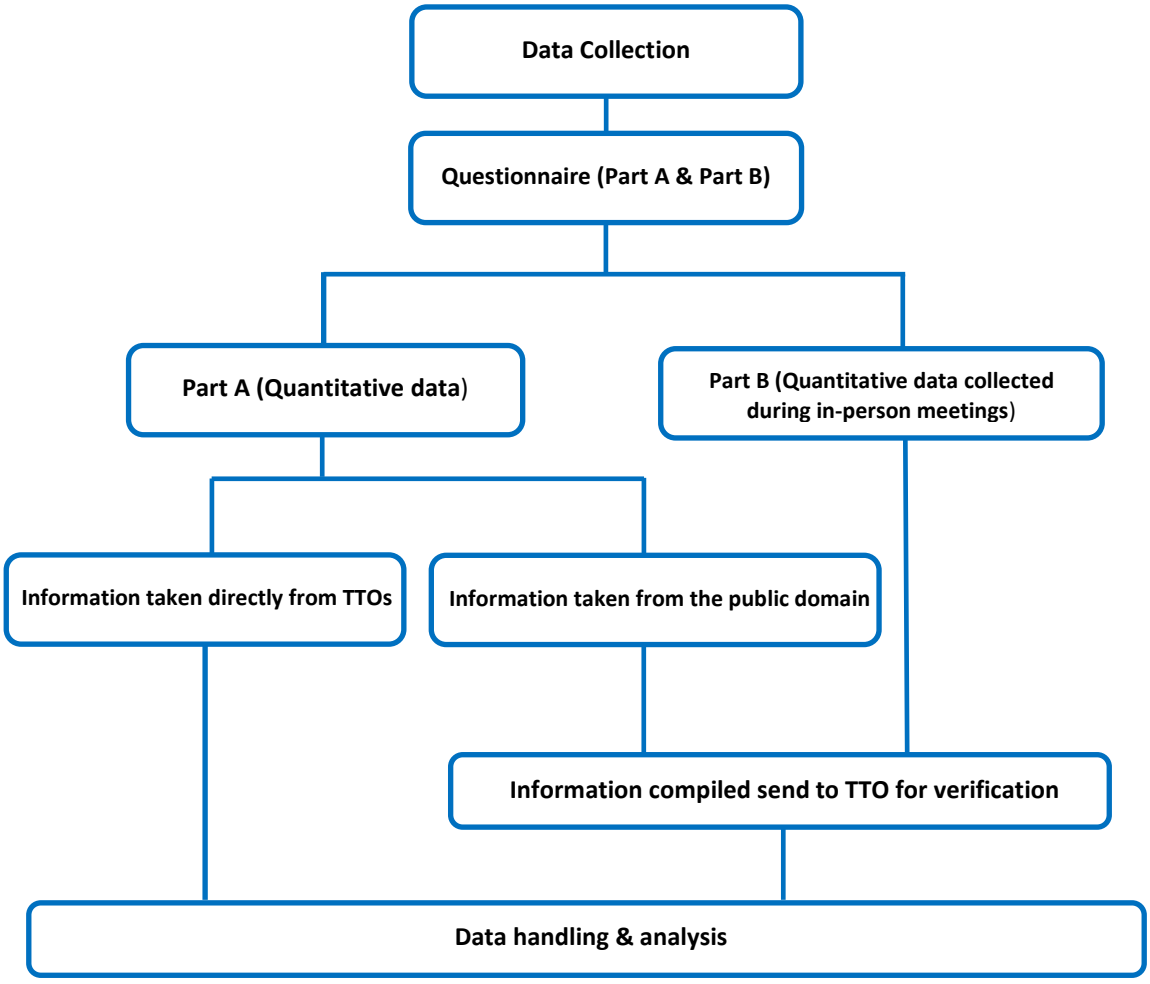

Figure 7: Data collection process

3.7.3 DATA WRANGLING

1. **Data archiving** - Data gathered in the form of responses of questionnaire Part A and Part B after verification was merged and archived. All the responses of questionnaire Part A and Part B was taken as raw data for further steps.

2. **Data structuring**- Unprocessed raw data was converted to the format that can be easily used by addressing the Incomplete or improperly formatted entries. Relevant information was extracted and structured in a spreadsheet.

3. **Data cleaning** – Eradication of errors and remediation was carried out in this step to downsize the skewness of the data. Outliers' identification, coping null values, incorrect inputs, duplicity, elimination of structural problems was taken care of. Optimization of the accuracy of data for further analysis was ensured.

4. **Data type identification** –The clean data was classified into two types: Qualitative Data (descriptive clean data) and Quantitative Data (numerical clean data-discrete and continuous). SWOT responses taken under quantitated continuous data were further separated out.

5. **Data representation** – Quantitative discrete data was represented in binary '1' for Yes or '0' for No responses; time frame data in years; financial data in crore. A bar graph was used to visually interpret the data, such as depicting the Year of establishment, function of TTOs, TTO Manpower distribution, etc. Qualitative data such as constraints, TTO steps, capacity building, and formal and informal channels were standardized and organized by classifying them into categories to remove the variation and repetitiveness in responses by the TTOs. Quality metrics for easy handling were then structured to put the organized qualitative data of TTOs responses under each category in binary '1' for Yes or '0' for No responses.

6. **Data Validation** -Both data types, Qualitative and Quantitative, were processed for validation to ensure the data accuracy and consistency. Data available in the public domain of all the TTOs was again checked and verified by the respective institution. TTOs were approached from time to time to ensure the data accuracy.

7. Based on the desk research of the five international ecosystems studied as part of this work and the TT models available in the literature, a comparison was drawn with the current operational practices in the Indian TT ecosystem. This exercise helped identify the current gaps and areas requiring further attention. The findings have been summarized and presented as a suggestive operational model for the Indian TTOs and TTCs.

FINDING AND DISCUSSION

4. Findings and Discussion

The findings of the study, based on the desk research and the in-person visits and interactions, have been discussed in this chapter. The findings and discussion have been organized per the seven attributes and sub-attributes covered in other parts of the study. Most of the findings have been presented in percentage of the responses received. The information presented in this chapter provides the as-is status of the TT ecosystem in India and does not provide any reasoning, explanation and conclusive correlations of the as-is status. Section 4.1 discusses the findings from the national TT ecosystem. These findings are based on desk research and data collected during in-person visits to the select 25 TTOs. Section 4.2 discusses the international ecosystems of five countries: Switzerland, USA, South Korea, Germany and Israel. This information is presented based on the data collected through desk research. Table 10 compares the international best practices in TT viz-a-viz the practices in the Indian TT ecosystem. Detailed information on each of the five international innovation ecosystems has been provided in Annexure II.

4.1 Data interpretation

Refined data after data wrangling was then used to populate the Characterization Matrix. The characterisation Matrix was structured per the process described in section 3.5. The responses in the form of indicators and sub-indicators became the rows of the Characterization Matrix, and 25 TTOs formed the columns of the Characterization Matrix. The populated Characterization Matrix was then analysed to understand the 'as-is' status of the Technology Transfer ecosystem at the national level. The following observations were drawn.

4.1.1 Establishment of TTOs

The number of TTOs established during each time cycle of 10 years, starting from 1970 till 2020, was analysed (Figure 8). The highest number of TTOs (10) were established during 2010-2020 and were reported based on the responses of 25 TTOs. The information in Figure 7 shows that the TT journey of the Indian innovation ecosystem started in 1970-80. This was also when the Indian Patent Act of 1970 came into existence and practice. This Act has played a significant role in shaping India's approach to intellectual property and innovation. The number of TTOs established has increased from 2010 onwards, which directly impacts the initiatives the Government of India took at the national level (Kumar & Jain, 2002; Ramya and Janodia, 2021).

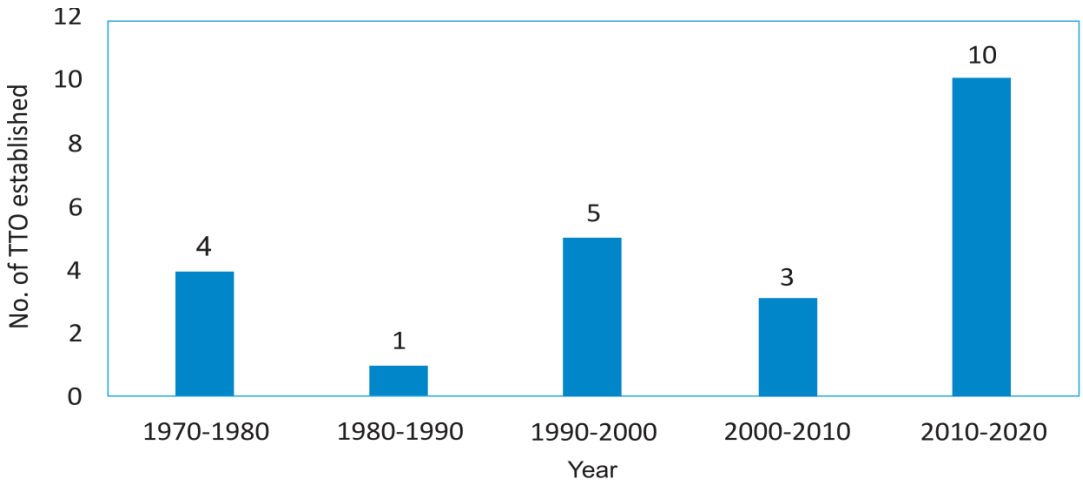

Figure 8: No. of TTOs established during each time cycle of 10 years, from 1970 till 2020

Some of the initiatives contributing to this growth are:

- NSTEDB 2009 (Established by DST)
- Ease of T&C for researchers planning to Startup
- Startup India program and other support schemes
- Make in India Initiative 2014
- AICTE training and learning academy
- IPR Chairs

4.1.2 Legal status of TTOs

The 25 TTOs reported in Figure 9 are hosted at HEI (Public funded and private (state private or deemed to be)/NRLs. The legal status of these TTOs was majorly reported as Public (60%), while less than 1 % reported private/PPP/NGO/Trust/ non-profit company. The TTOs received funds through various schemes of GoI, such as the Department of Science and Technology (DST) or the Department of Biotechnology (DBT). In due course of time, attempts to achieve self-sufficiency were preferred; less than 1% have a self-sustained structure till now. The self-sustaining TTOs have sponsored research and consultancy, EIR (Entrepreneur-in-Residence), Corporate Innovation, and Social Innovation as significant sources of revenue.

4.1.3 TTO Structure

TT governance and administration were reported from the responses received from 25 TTOs that are part of HEIs and NRLs. It was reported that 54 % of TTOs have a board of governance, which may comprise a director/ head, governing council/executive board and coordinating team for administration, finance and manpower for TT operations. The responsibilities related to TTO functioning, monitoring and channelizing the everyday affairs of TTO, such as outreach, management, finance etc. lie with the board of governance.

The Team leader characteristics were also analysed Items such as the years of experience in the domain of TT, independent or additional charge and type of responsibilities were covered. It was observed that most of the TTOs have team leaders appointed from the faculty/scientists of the host institution. It was reported that a minimum of 10 years, on average, is the experience required to be appointed as the team leader. However, there was an overlap between the experience required for TT and the experience gained during R&D in their respective sectoral domains. 36% reported that the leadership has an independent charge. It was also observed that the Team leader is usually appointed from tenure-oriented administrative posts such as Dean (R&D) and Director (R&D).

Finance, Experts with industry experience, and any other expert panel/pro-bono/high-level expertise were the TT domain experts reported in this study (Figure 8). Highest no. of experts reported in the domain of IP protection and Management (54%), followed by experts with Industry experience (48%), Marketing (43%), Technology Protection and Management (38%), Legal (36%) and Finance (30%). The ratio of part-time experts vs full-time experts working as staff in a TTO was calculated for each domain. The ratio was higher for IP protection and management (42%), followed by experts with Industry experience (37%), Marketing and Finance (30%). The ratio was lower for the Technology protection and management (26%).

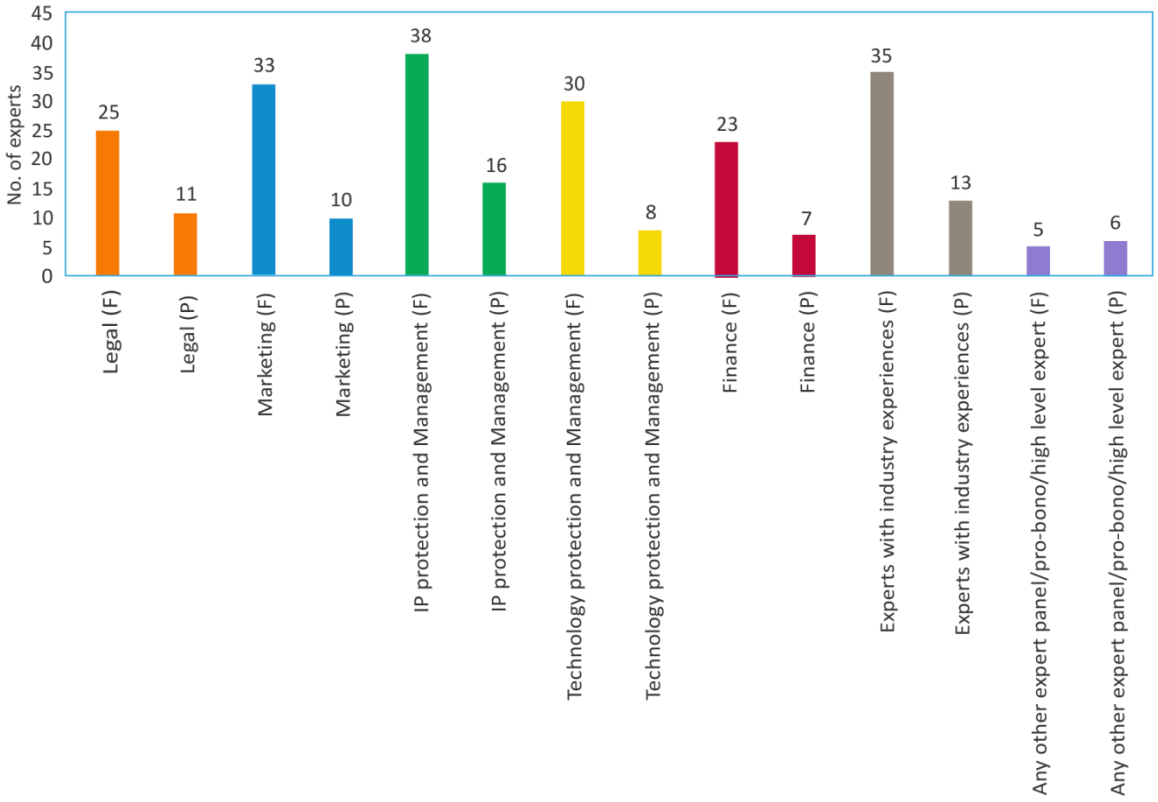

Figure 9: TTO staff variation in terms of Full Time (F) vs. Part-Time (P) in various working domains of TT

4.1.4 TTO Functionality

This section covers the questions intended to get insights into the current level of technology transfer and commercialization activities being carried out in the TTOs covered in the study. A few examples of the information sought for further analysis are (Figure 10):

- Total number of technologies generated (by the host institute) since 2015.
- Total number of technologies commercialized since 2015.
- Number of patents filed since 2015.
- Number of patents granted since 2015.

Based on these data points, responses were received from all TTOs covered in the study – the responses they received revealed interesting numbers and underlying assumptions. Some TTOs responded that their number of patents applied equals the number of technologies generated, while in some other cases, the number of patents licensed was reported as the number of technologies commercialized; in some other cases, the number of technologies commercialized reported was much higher than the number of technologies generated for the time period.

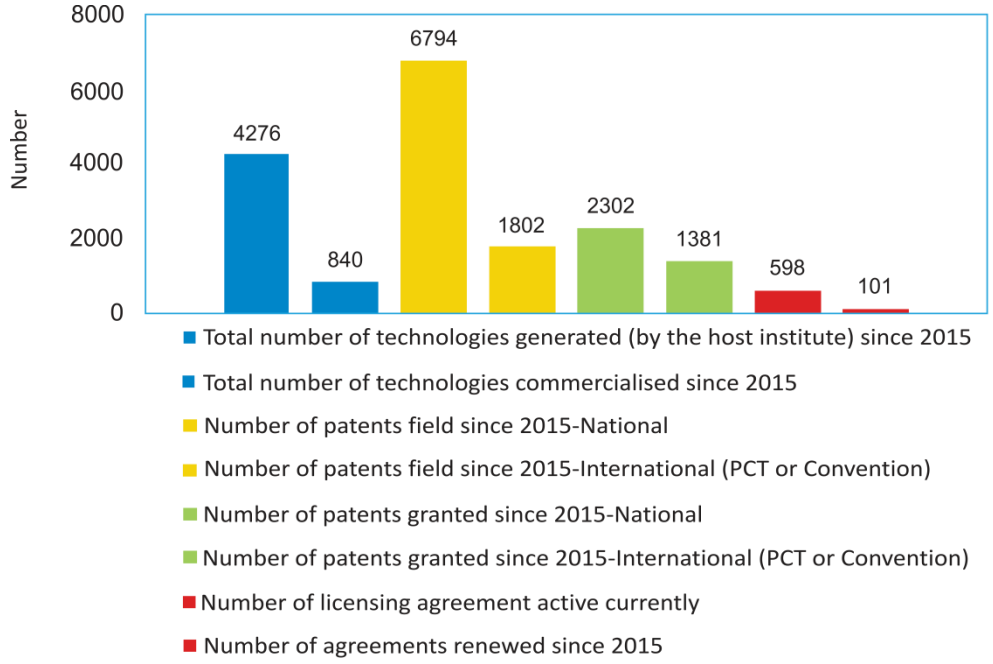

Figure 10: Type of TTO functions and their quantities

Further investigation and discussion with the responding TTOs showed that each institute perceived common TT terminology of patents filed, patents granted, technologies generated, technologies commercialized, and patents licensed differently. Moreover, certain underlying assumptions, such as one patent = one technology; patent licensed = technology commercialized, made analysing this data set extremely difficult. Given the disparities in reporting by various TTOs, there is an urgent need for apex-level guidance to the Tech transfer ecosystem in terms of standardization of definitions, concepts and fundamentals related to establishing and functioning of TTOs.

4.1.5 TTO Operations

In TTO operations, 88% TTOs reported doing in-house technology assessment and 76% TTOs reported doing in-house technology valuations. Only 12% of the TTOs reported that they outsourced technical assessment and valuation activities. Further, it was reported that 60% of TTOs have minimum criteria of the selection technologies/knowledge for transfer and commercialization. However, the approach for TRL assessment needs was not provided by the TTOs except for less than 1% of responses. It was inferred that there should be minimum benchmarking for TRL while assessing the technology. Only 28% of TTOs responded against the intake requirements for an application to be selected by the TTO for further processing. However, no specific criteria were observed in this case. 88% of TTOs reported doing in-house IP management.90% of TTOs provide entrepreneurship assistance, while 63% of TTOs provide technology incubation services. 68% reported consultancy to facilitate TT as an additional activity. Apart from these activities, 80% reported co-commercialization with other organizations.

4.1.6 Types of contracts and agreements

In regards to contracts and agreements, 76% of TTOs reported a preference for non-exclusive licensing. While 64% of TTOs reported doing joint venture agreements with other institutes or industries. Master Research Agreements (in case of co-ownership) and Joint Development Agreement were some of the other Mode/Mechanism 80% of TTOs reported signing non-disclosure agreements (NDA) followed by Material Transfer agreements (MTA) (64%) and Knowledge Transfer Agreements (KTA). 60% reported doing Cooperative Research and Development Agreements (CRADA) and Confidentiality agreements. 48% reported Data use agreement. The other types reported are sponsored research agreements, joint research agreements, Trial licenses, equity (start-ups) and option agreements.

4.1.7 TTO policies

- **The existence of a dedicated** policy for Technology Transfer, Intellectual Property Management (IPM), and policy to promote entrepreneurship within HEI was analysed. 96% have dedicated IP Policies designed at the institutional level or following the IP policy laid down by CSIR and IITs. 72% of TTOs reported the existence of guidelines for their TT process; however, they are part of the IP policy. No dedicated TT policy was observed. 60% of TTOs reported a dedicated Entrepreneurship support and promotion policy.
- **Percentage of ownership:** 84% of TTOs reported that the ownership of the patent generated rests with the host institution, while 20% of TTOs reported the share to the funding agency. 32% of TTOs reported doing joint ownership.
- 88% of TTOs reported that faculty/scientists of the host institution have the opportunity for Incentives/Royalties (monetary or non-monetary) for doing technology transfer as per "Incentive for TT" guidelines. 20% reported the 80% of the share goes to the host institution while 20% goes to the inventor. 32% of TTOs reported that 60% of the share goes to the host institution while 40% goes to the inventor.
- Guidelines for inbound TT were reported only by 28 % of TTOs.

4.1.8 Engagements with industries/HEIs & NRLs/international organisations

- Relationships with industries: 72% of TTOs reported proximity to the relevant industry. TTOs use formal and informal channels to engage with the industry. 84% reported using formal engagement channels with the industry, and 72% reported using informal channels.
- Partnerships and collaborations to enhance technology transfer (MOUs) Signed between TTO and HEI/NRL, Industry, intermediaries (NGOs, Trusts, etc.) and international organizations were reported. 52% of MoUs are signed with the industry. Less than 10% of MoUs are signed with other academic and R&D institutions. 13% engagement with other National Research Laboratories was followed. Engagements with international organizations and other Higher Education Institutes (HEIs) were reported as 6% and 4% of MOUs signed. 3% engagements were reported with other institutions (NGOs, Trusts, etc.)

4.1.9 Reporting and Performance Review

- TTOs publish annual performance as a part of the host/parent institution's annual report, and no dedicated monitoring, reporting or performance review framework was reported. Only the TTOs (i-TTOs) established under the National BioPharma Mission have a dedicated reporting framework for reporting and performance review.
- 64% of TTOs reported doing regular audits, while 56% of TTOs reported their activities in the Annual assessment report of the host institution.

4.1.10 Marketing, Promotion and Outreach

- Preferred Marketing and Promotion channels for TTOs were the digital/Social media. 68 % of TTOs reported having dedicated digital platforms, such as websites and social media channels, to showcase their information, data, and technologies. 32% reported using print Ad media, and 60% reported using personal visits to showcase the activities of their organization. Less than 1% reported the use of telecommunication for outreach and showcase.
- 72% TTOs reported the update to date website with cycle of update is 02 months. 24 % TTOs reported the presence of its own marketplace to facilitate technology with cycle of update is 01 month.

4.1.11 SWOT Analysis

SWOT analysis was conducted during in-person visits. TTOs scaled their Strengths, Weaknesses, Opportunities and Threats on a scale of 1-5. The percentage of each respective parameter of Strengths, Weaknesses, Opportunities and Threats was calculated from the scale score given by respective TTOs. Based on the percentage of the scores of these parameters, Strengths, Weaknesses, Opportunities and Threats for TT ecosystem at the institutional level were understood.

Strengths: Parameters of strength were Trained TT personnel, Networks, Modern equipment/infrastructure, Scientific sectoral approach, and Financial and Administrative independence; considered to provide a competitive advantage to TTOs at the institutional level. Percentage score of strength parameters is given in Figure 11 (a).

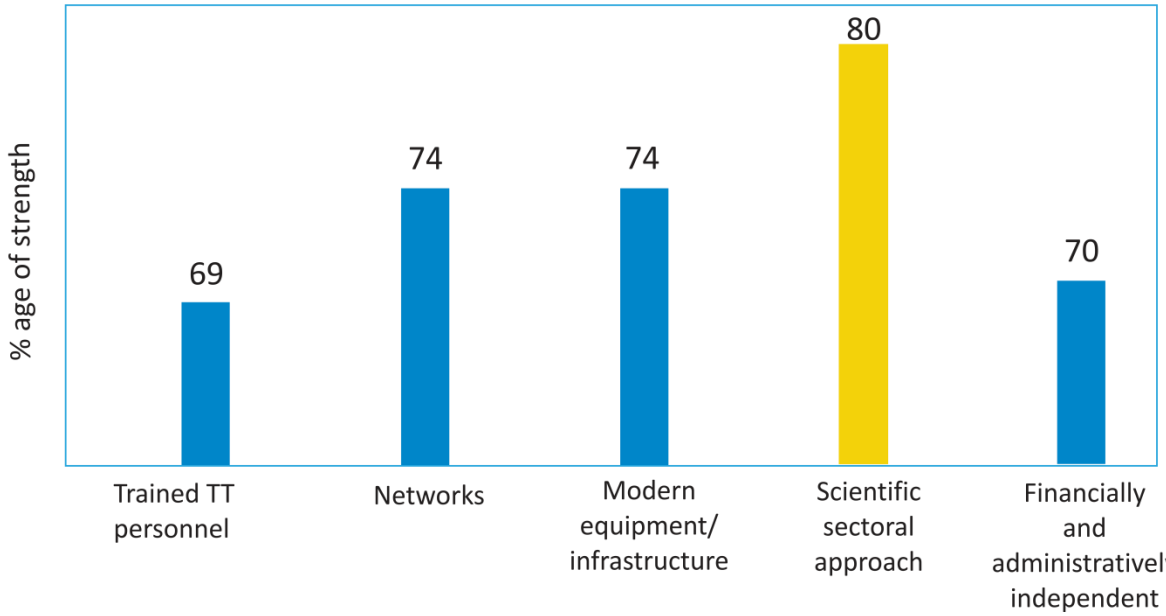

Figure 11 (a): Percentage of strength parameters identified for SWOT analysis

'Scientific sectoral approach' got the highest percentage (80%) and hence identified as the critical parameter for strength. TTOs consider themselves highly skilled in their particular sectors and strongly agree that skills development meets the needs of the industry concerned. 'Networks' and 'Modern equipment/infrastructure' got a 74% score. 'Trained TT personnel' and 'Financially and Administratively' came out to be parameters with lower strength (70%), which highlights the need for skilled manpower for TTO with independent and improved financial and administrative support to TTO.

Weaknesses

Strategic vision of the TTO, Income level of research workers, technical expertise as per the local industries, Interest of private sector industries in research and technological development, relevant training and experience required for TTO function were the parameters of weaknesses considered under context. Improvement in these elements can enhance the efficiency of the TTO functioning. The percentage score of weakness parameters is given in Figure 11(b). 59% score to the parameter 'Relevant training & experience' depicts the need for capacity building in various aspects of the TT process felt by the TTOs.

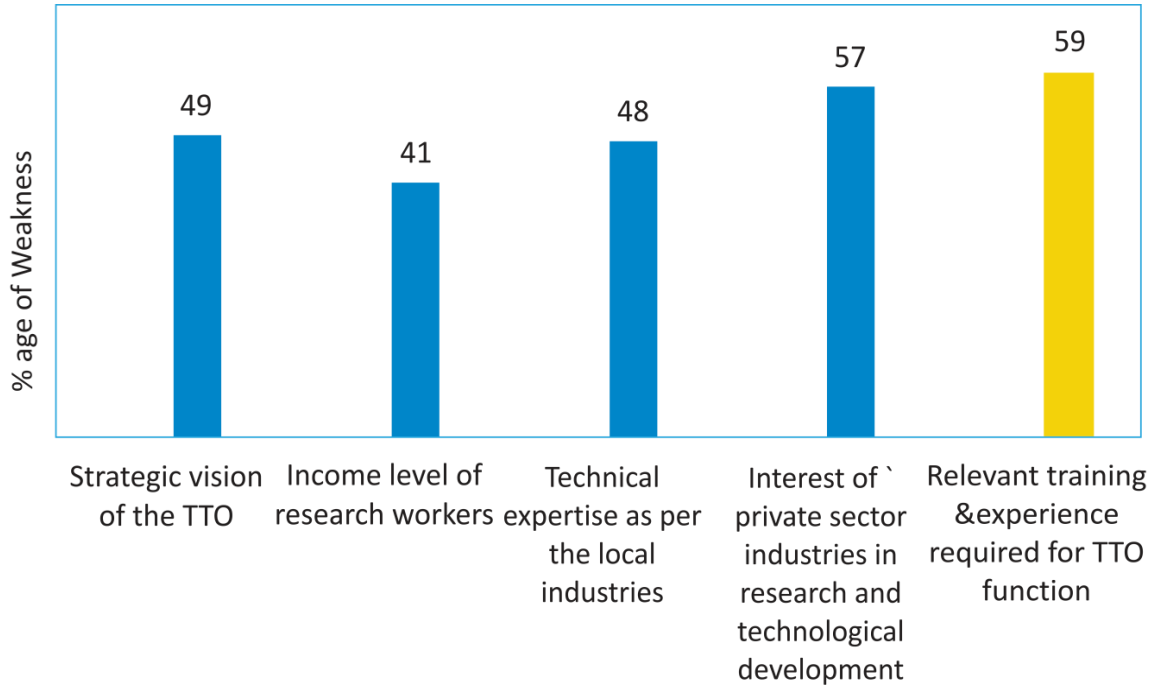

Figure 11 (b): Percentage of weakness parameters identified for SWOT analysis

Enhancing the activities in this regard might be required. The 'Interest of private sector industries in research and technological development' parameter (57%) needs further strengthening of the Industry and Academia relationship, removing any gap in communication, expectation and trust. All the TTOs were well satisfied regarding the income level of research workers (41%). The need was felt to enhance the technical expertise of the local industries (48%) by identifying the interest domains of industry in R&D of the host institution. A prominent strategic vision for the TTO (49%) is the need of the hour as it channelized the whole TT operation at a TTO.

Opportunities

The parameters for opportunities were Young human capital capable of keeping pace with scientific and technological progress. The ability to enter new markets, Collaboration among various stakeholders, A promising local market for investments, and Opportunities for international cooperation. Percentage score of opportunity parameters is given in Figure 11(C).

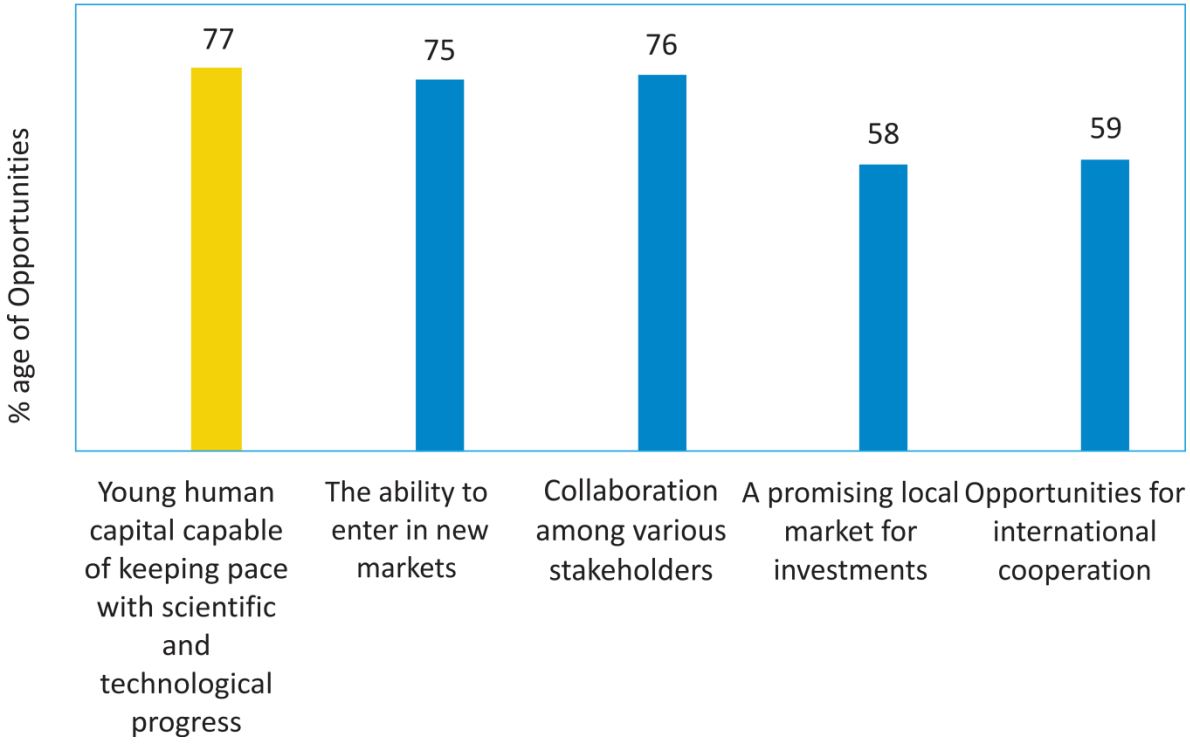

Figure 11 (c): Percentage of opportunities parameters identified for SWOT analysis

The parameter 'Young human capital capable of keeping pace with scientific and technological progress' came out to be the leading parameter in terms of opportunities (77%). With 76%, the parameter 'collaboration among various stakeholders' depicts a little push for this opportunity to become the strength of a TTO. It has been observed that the TTOs have the ability to enter a new market for investments (75%) however it may require channelization and more outreach activities. Exposure and momentum are required for international cooperation (59%) and to build trustworthy relationship fora promising local market for investments (58%).

Threats

Threats are external factors that are difficult to control, but efficient management can reduce the damage. Brain drain and competence drain (attrition), Slow pace of economic reform, slow pace of administrative reform, Slow development of education and training systems and curricula, Lack of incentives for the private sector to invest in research, and Complex procedures for creating start-ups were the parameters considered for threats. The percentage score of threat parameters is given in Figure 11 (d).

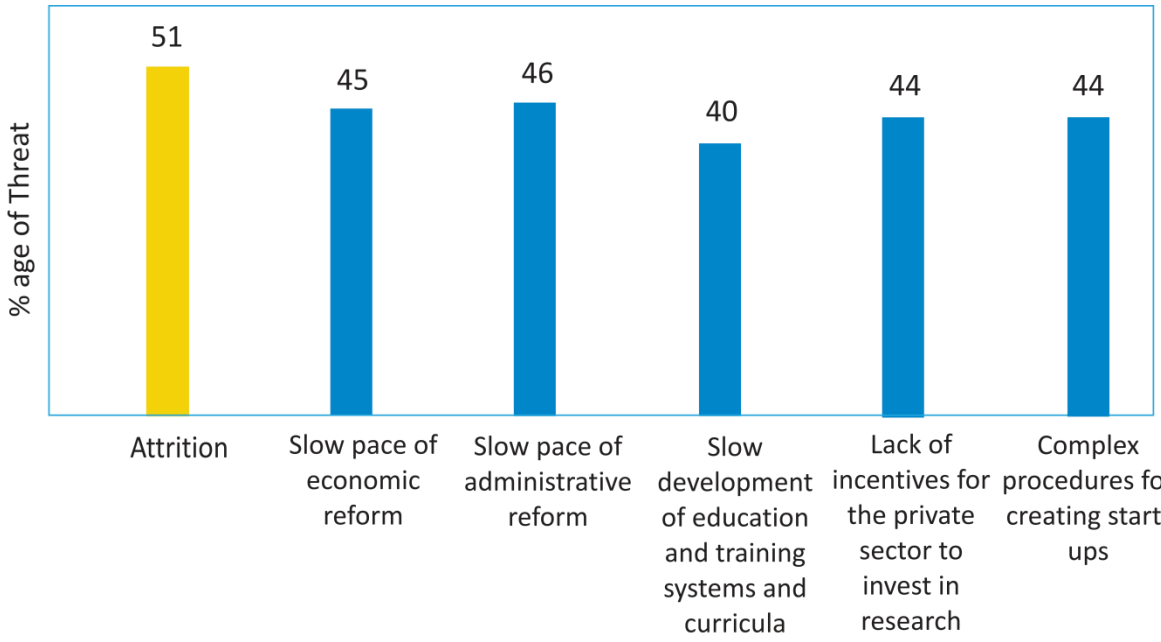

Figure 11 (d): Percentage of threat parameters identified for SWOT analysis

The highest percentage (51%) for the parameter 'Brain Drain and Competence Drain(attrition) signifies a critical threat to lose the expertise of the manpower in the respective TT domain as TTOs already responded 'Relevant training & experience' in TT as their highest weakness. Slow pace of administrative reform (46 %), 'Slow pace of economic reform' (51%), lack of incentives for the private sector to invest in research (44%) and Complex procedures for creating start-ups (44%) showed a need for better processes to attract entrepreneurs and private investment in the TT domain. 'Slow development of education and training systems and curricula' (40%) was not considered a significant threat due to the strong economic push provided by the host institution and the strong backing of education culture at the host institution promoting the TT ecosystem.

4.1.12 Constraints Identified by the TTOs

During the in-person visits, TTOs were asked to mention any constraints encountered during the Technology Transfer process. Table 7 shows a List of solutions suggested by TTOs to remove the constraints in their functioning.

Table 7: Constraints reported by TTOs

Constraints reported by TTOs	Possible solutions suggested by TTOs
National TT policy and guidelines	• Best practicess from more developed ecosystems can be studied and adapted to the needs of the Indian TT ecosystem.
Institute-level TT policies and guidelines	• National and International best practicess can be studied for reference. • Focused mentoring by more developed TTOs to help the emerging TTOs develop.
Skill upgrade and capacity development	• Development of a series of specialized capacity-building program focused on building skills of TT.
Attrition	• Development and standardization of roles and responsibilities and career progression chart in the TT domain. • Best practicess from more developed ecosystems can be studied and adapted to the needs of the Indian TT ecosystem.
Team size and structure	• Referencing and benchmarking with the current global practices.
Funding	• Training on writing proposals, effort estimation and budget planning. • Awareness program on different sources of funding.
Industry-Academia linkages	• Creation of platforms to enable knowledge exchange and experience sharing. • Improve internal team communication and outbound communication. • Leverage the different outreach platforms to reach a targeted, diverse audience.
Market Intelligence and Expectation Mismatch	• Strengthen the industry-academia linkage. • Creation of a common platform for knowledge exchange and experience sharing. • Create opportunities for involving industry and end-users in the early R&D and technology development stages.

4.1.13 Expertise and Exposure Required by TTOs

In addition to the inputs provided by the TTOs, information related to the various National/ International expertise and exposure were also provided.

Following is the list of specific topics suggested by TTOs for mentoring and expert training:

- Technology evaluation and estimation of the Return on investment.
- Equity model of technology transfer as practised internationally.
- Flexible business models for more creative TT offerings.
- Project and timeline planning and management.
- Effective organization of technology showcase at the regional, national and international level.
- Leveraging of collaboration projects and researcher exchange.
- Setting up internal policies and guidelines for monitoring TT performance.
- Flexible term-sheet models for drafting/designing deals for licensing.

4.1.14 Technology Transfer steps followed by TTOs

Responses of TTOs received for various steps followed for the Technology Transfer (TT) at their institution were noted. All these steps were organized into normalized steps for the standardized practised steps followed globally (Ramanathan, 2009; Bahr, 2022; Manikandan and Kathiresan, 2021; Van Norman and Eisenkot, 2017; Mamat and Roslan, 2012; Gibson, 2005; University of Pretoria, n. d.; Lane, 1999) for Technology Transfer. The normalized steps for TT are mentioned below, starting from the R&D to developing healthy partnerships after Technology Commercialization. All these steps might be overlapping in some cases. However, the perspective of each TTO in defining the TT process is captured. Steps followed by TTOs were reported in the second column as 'steps reported for Technology Transfer by TTOs'. The TT process through normalized steps is as follows

Step 1- Research & Development: 44% of TTOs reported the first step of the TT process is R&D. TTOs highlighted the following key sub-steps involved in the first step of the TT process.

a. Identification of the problem and its potential solution.
b. Identify where opportunities lie.
c. Investigation, development, and creation of new items and technology.
d. Research and development.
e. Successful culmination of laboratory work and the development of a prototype.
f. Technological development.
g. Create deep tech products.
h. Product development.

Step 2- Technological evaluation: 72% of TTOs reported technology evaluation as one of the preliminary steps of the TT process that brings out the innovation to the product stage that could be termed as Technology after a series of investigations and consideration, following sub-steps reported in step 2.

a. Preliminarily assessment of innovations
b. TRL evaluation
c. Sectoral approach of technology
d. Technology impact assessment
e. Technology economic assessment
f. Technology socioeconomic impact assessment
g. Commercial potential
h. Market analysis of the technological field to understand its market relevance
i. Identify the end-use, utility, and due diligence of the interested parties
j. Follow up on the improvement of technology and its validation

Step 3- IP and marketing: All TTOs reported IP and marketing as a crucial step the of TT process, following sub steps reported towards step 3.

a. Inventor approaches to TTO
b. Patent feasibility
c. An expression of interest from the innovator.
d. Invention harvesting
e. Prior Art search
f. Patent application drafting
g. Filling of Patent
h. Grant of Patent
i. Patent generation
j. IP management
k. economic potential assessment before beginning the process of commercialization
l. Establishing communication with an appropriate commercial collaborator
m. Market the technology
n. Disclosure of technology for validation
o. Technology valuation
p. Inventor's involvement to explain or demonstrate the developed technology throughout the procedure

Step 4-Negotiation and contracting: Another essential step of the TT process is negotiation and contracting. 68% of TTOs reported this the as threshold step of Technology commercialization. Following are the sub-steps reported for step 4.

a. Demonstration of the technology
b. Negotiation
c. Revenue management
d. Documentation
e. Execution of associated agreements/Licensing/Contracting
f. Signing of agreement
g. Periodic tracking as a part of the contract

Step 5- Technology transfer and commercialization: In TT and commercialization, 44% of TTOs reported this step as the final step of technology transfer, which involves the following sub-steps identified during reporting.

a. Technology transfer to a commercial partner
b. Incentives share distribution
c. Scaling up technologies in partnership/TRL upgrade
d. scale production
e. Collaboration with industry for the commercialization of newly created technologies/products through transfer of technical know-how / Technology Transfer
f. Scaling up technologies in partnership/TRL upgrade
g. Technology Management-maintain and upliftment

4.2 Overview of Innovation and Technology Transfer Ecosystem of Selected Countries

The international study on innovation ecosystems, encompassing five leading innovation countries, aimed to gain insights into their critical attributes in terms of global positioning, inputs, and outputs. The study provides an innovation profile of these countries, emphasizing their unique characteristics that contribute to strengthening their innovation and Technology Transfer ecosystems.

The five selected countries, Switzerland, The United States of America (USA), the Republic of Korea (S. Korea), Germany and Israel, are innovation leaders worldwide, showing extraordinarily positive and significant relation between innovation and development. Innovation profiles of the selected countries in detail have been given in Annexure II.

Key characteristics of these selected innovation ecosystems that contribute significantly to their success are as follows:

- **Substantial R&D Investments:** All five countries allocate a significant portion of their GDP (more than 3%) to R&D expenditures. The USA is, in fact, the world's largest R&D investing country (Figure 12). Israel and South Korea stand out with more than 4% of their Gross Expenditure on R&D (GERD) as a percentage of GDP, indicating a strong commitment to national R&D investment.

The national R&D investments by these five countries are highlighted in Figure 12 and Figure 13.

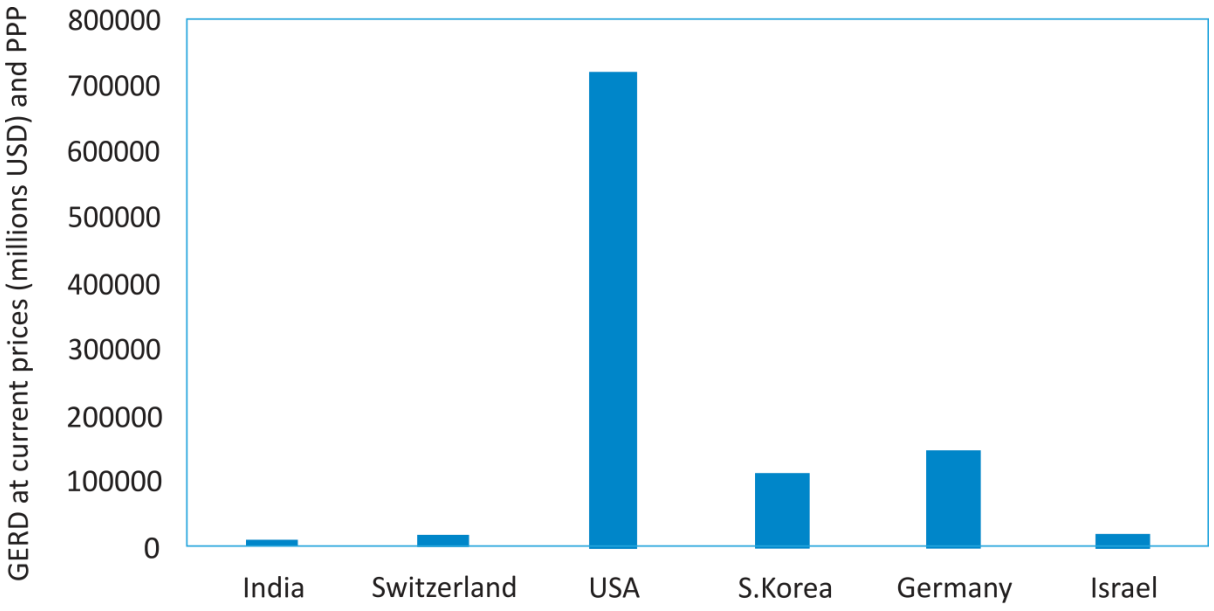

Figure 12: The R&D investments of select innovative countries

GERD as % of GDP highlights the country's commitment towards the R&D ecosystem. On the one hand, India ranks among the top 10 nations in the world regarding R&D investments. However, India's GERD has remained stagnant at 0.7% for over a decade when considering its GDP contribution. To revamp India's research and innovation ecosystem, there is a need to boost the GERD's share to the GDP.

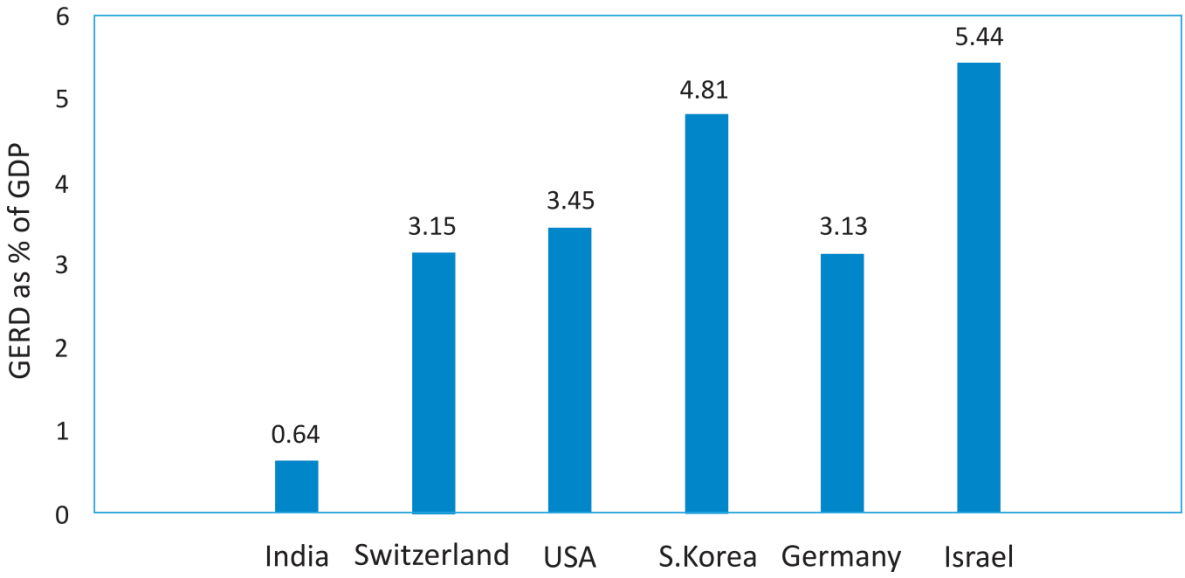

Figure 13: The GERD as % of GDP by select innovative countries

- **Private Sector Engagement:** These countries demonstrate high private sector participation in their national R&D ecosystems, with over 60% of national R&D conducted by the private sector. This highlights an industry-led approach to R&D and innovation, reflecting their outcome-oriented focus. Figure 14 highlights the high percentage of industry participation in the national R&D investment ecosystem of the five select countries that showcase industry commitment towards R&D. As observed for India, the government sector accounts for 60% of R&D investments, while the private sector's contribution to the national R&D ecosystem is below 40%. To foster a thriving R&D landscape, India must actively encourage greater participation from the private sector, as observed in most innovation-driven developed economies.

- **Robust Innovation Input Components:** The innovation ecosystems of these countries exhibit vital input components, including R&D infrastructure, human resources, and R&D investments. Their representation in terms of R&D investments, percentage of GDP allocated to R&D, and Full-Time Equivalent (FTE) in R&D is comparatively higher than other countries, contributing to a strengthened R&D and innovation ecosystem. All these countries have progressive positioning in innovation outputs in terms of knowledge and creative inputs reflected in their high number of publications, patents, technology exports and innovation linkages.

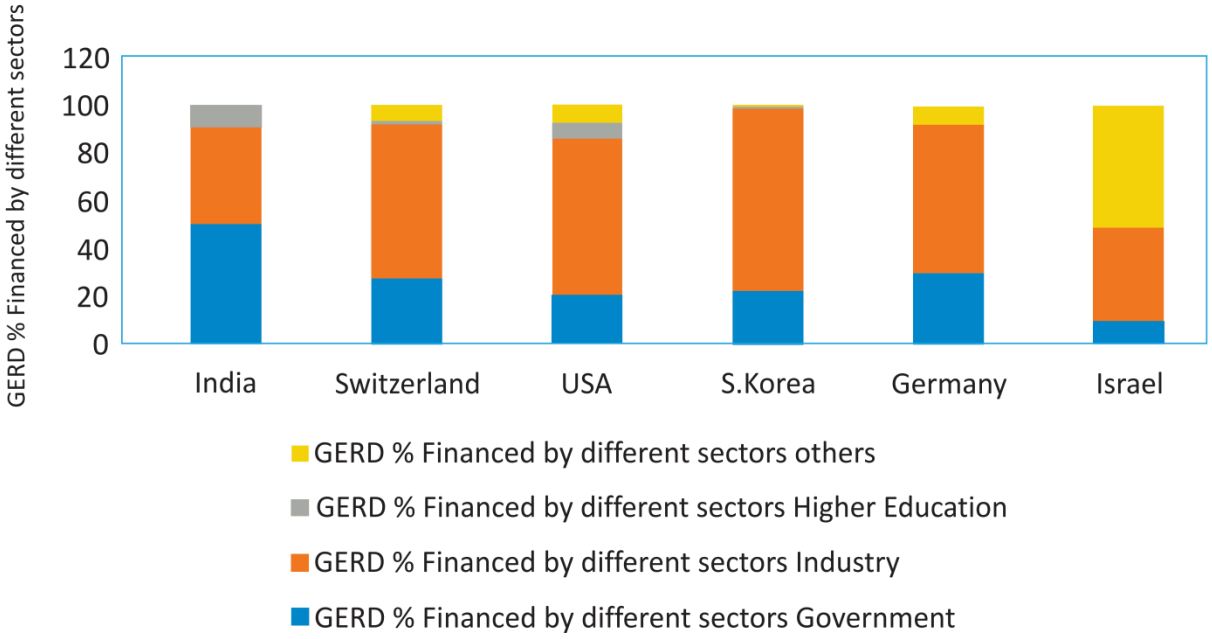

Figure 14: GERD % Financed by different sectors (2021; data for Switzerland and Israel is from 2019)

A matter of concern in India is the limited number of FTE personnel engaged in R&D. With only 250 FTE (Ministry of Science & Technology, GoI, 2021) per million population dedicated to R&D, the current figure raises significant concerns about the nation's R&D capacity and capability. India's scientific work in the publication has also shown a rising trend for the past decade, with a growth rate in scientific publication of 8.4% against the world average of 1.9% (as per Scopus). India is in 9th position in the world in resident patent filing activity, but the numbers dip in patents granted and licensed.

Table 8 highlights the significant contribution of R&D resources for building the R&D and innovation base in the country.

Table 8: Human Capital in R&D in the selected countries

Countries	Total Researchers as Full-Time Equivalents (FTE)	FTE per 1000 total employment	GII Rank in Sub indicator of Human Capital and Resources
Switzerland	47,699	9.4	12
USA	15,86,497	9.9	19
South Korea	4,46,739	16.6	1
Germany	4,50,796	10	14
India	361,924	7	51

***Data not available for Israel**

- **Effective Governance of Innovation:** These countries have well-defined governance structures and legislative frameworks to promote R&D and innovation. Examples include the Bayh-Dole Act in the USA, the research innovation bill in Switzerland, and dedicated Science and Technology (S&T) plans in South Korea, released every five years to align with changing trajectories and national priorities.
- **Interconnected Innovation Actors:** The role of innovation actors and their linkages play a crucial role in building robust innovation systems. Table 9 below highlights the critical innovation actors of select five countries that play a crucial role in shaping the innovation ecosystem in their respective countries.

The Technology Transfer ecosystem study of the five selected countries was also undertaken. The key attributes that contribute to strengthened Technology Transfer ecosystems of these countries are also presented in Table 9.

Table 9: Selected five countries and their key innovation actors as well as Selective Key Attributes of Technology Transfer Ecosystem of the Selected Country

Sr. No.	Country and Brief details	Selective Key Attributes of Technology Transfer Ecosystem of Selected Country	Key Stakeholders (with examples)
1.	**<u>Switzerland</u>** Switzerland has a global reputation as one of the most innovative countries globally. It ranks first per the GII report 2022 and has held this position since 2011. Switzerland has the highest number of Nobel Prizes per capita and a strong network of industry and academia. Switzerland's budgetary allocation for R&D is around 3% of its GDP. Switzerland stands 4th place worldwide in Research and Development (R&D) investment. The Swiss Federal Government has a dedicated Federal Act for promoting Research and Innovation (RIPA), which is amended as per the ongoing needs The RIPA lays down rules and regulations for planning, quality assurance, and coordination measures to be taken by Federal agencies to enhance the efficiency of the Swiss innovation system with an emphasis on knowledge transfer. Details of Swiss innovation ecosystem is provided in Annexure II (b)	1. **Legislative Support:** The Research Innovation Bill of Switzerland has a well-defined legislative framework to promote Technology Transfer and innovation. The Research Innovation Bill outlines policies and measures to support knowledge and technology transfer from research institutions to industry, facilitating collaboration and commercialization. 2. **Innovation Promoting and Support Organizations:** Switzerland has dedicated organizations and initiatives to promote Technology Transfer and commercialization. Institutions like **Swissnex, Innosuisse, and the Swiss Federal Institutes of Technology (ETH Zurich and EPFL)** are crucial in connecting academia, industry, and startups, facilitating knowledge exchange and technology commercialization. 3. **Establishment of TTOs:** Swiss research institutions and universities have established TTOs that specialize in managing intellectual property, facilitating licensing agreements, and supporting spin-off ventures. These offices bridge the gap between academia and industry, promoting the transfer of technology and fostering entrepreneurship. 4. **Strong IP Protection:** Switzerland has a robust IP protection system that encourages researchers and innovators to disclose their inventions and secure patents. The strict enforcement of IP rights provides legal safeguards and incentives for Technology Transfer, fostering a favourable environment for innovation-driven partnerships.	**Government:** • Federal Department of Economic Affairs, Education and Research (EAER) • State Secretariat for Education, Research and Innovation (SERI) • Swiss Agency for Innovation Promotion (Innosuisse) **Industry:** • Roche holding AG (Health Sector) • Novartis AG (Healthcare) • Nestle (Food & beverages) • Syngenta AG (Agribusiness & Chemical) • ABB Ltd. (Electrical Equipment sector) **Academia and Research Institutes:** • Swiss Federal Institute of Technology Zurich (ETH Zurich) • Ecole Polytechnique Federale de Lausanne (EPFL) • University of Zurich • IDIAP Research

		5. **Strengthened Industry-Academia Collaboration:** Switzerland emphasizes strong linkages between academia and industry. Collaborative research agreements, joint ventures, and industry-led research initiatives foster the exchange of knowledge, expertise, and resources, facilitating Technology Transfer and commercialization. In addition, Switzerland actively participates in international networks and collaborations to enhance Technology Transfer. Switzerland has a thriving entrepreneurial culture and a supportive startup ecosystem. Incubators, accelerators, and entrepreneurship centres provide mentorship, funding opportunities, and business development resources to support the creation and growth of technology-based startups.	Institute • Swiss Federal Laboratories for Materials Science and Technology **Others (Intermediaries):** • Swiss Innovation Parks • Swissnes Network • SOCCER (Swiss Competence Centers for Energy Research)
2.	**<u>United States of America</u>** It is one of the world's most advanced and largest R&D spending countries and ranked 2nd in innovation ranking. It has a strong legislative framework for promoting innovation and the Technology Transfer ecosystem. The USA has long been at the forefront of cutting-edge science, technology and innovation. It has held its position because it is a principally free-market country with a highly competitive R&D ecosystem. The R&D ventures in USA are funded mainly through Federal government agencies and a private segment, including industries and not-for-	1. **Legislative Support:** The enactment of the Bayh-Dole Act in 1980 played a pivotal role in shaping the Technology Transfer landscape in the USA. It allowed universities, small businesses, and nonprofit organizations to retain ownership of inventions resulting from federally funded research, enabling them to license or commercialize the technology. 2. **Presence of Intermediaries and Support Organizations:** Various organizations, such as trade associations, industry consortiums, and Technology Transfer associations, actively promote collaboration, knowledge sharing, and Best practicess in Technology Transfer. They provide resources, training programs, and platforms for networking and information exchange among stakeholders. 3. **Establishment of TTOs:** The USA has a well-developed network of TTOs within research institutions, universities, and government agencies. These offices are responsible for managing intellectual property, facilitating technology commercialization, and forging partnerships with industry.	**Government:** • National Science and technology Council (NTSC) • Government's National Science Foundation (NSF) • Small Business Administration (SBA)'s Office of Innovation (OII) • Defence Advanced Research Projects Agency (DARPA) **Industry:** • Alphabet (ICT Services Sector) • Microsoft (ICT Services Sector) • Apple (ICT Producers Sector) • Facebook (ICT Services Sector) • Intel Corp (ICT Producers Sector)

	profit organizations (NGOs). In USA, the legal and regulatory framework is inclined towards innovation and encourages innovators to undertake risks and garner rewards allied with innovation. Modifications in the policy towards a more robust IPR regime were initiated in 1982 with the legislation that established the Court of Appeals for the Federal Circuit, which strengthened the protection granted to the patent holders that played a significant role in stimulating the Technology Transfer ecosystem in the country. The innovation system of the USA is exceedingly diverse and scattered and will help establish a best practices framework for Technology Transfer. Details of the US innovation ecosystem are provided in annexure II (c)	4. **Policy and program Interventions for Patent and Intellectual Property (IP) Protection:** The USA's robust patent system and effective IP protection mechanisms encourage researchers and innovators to disclose their inventions and secure IP rights. This fosters a favourable environment for Technology Transfer by providing legal safeguards and incentives for commercialization. 5. **Strengthened Industry-Academia Collaboration:** The USA encourages strong linkages between academia and industry to foster Technology Transfer. Collaborative research agreements, joint ventures, and sponsored research programs facilitate the exchange of knowledge, expertise, and resources between universities and industry partners. USA's entrepreneurial culture and ecosystem nurture innovation and Technology Transfer. The presence of numerous technology incubators and accelerators across the country provides valuable support to startups and entrepreneurs. The availability of diverse funding sources, including government grants, venture capital firms, angel investors, and corporate partnerships, fuels Technology Transfer in the USA. Funding mechanisms such as Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs provide financial support to early-stage research projects with commercial potential.	**Academia and Research Institutes:** • Harvard University • Massachusetts Institute of Technology • Stanford University • Joint BioEnergy Institute • National Center for Biotechnology Information **Intermediary System:** • National Institute of Health (NIH) • National Network for Manufacturing Innovation (NNMI) • Incubators and Accelerators • Regional Innovation Clusters
3.	**<u>Israel</u>** Israel holds 16th rank in the GII report 2022 and 1st rank holder amongst the North Africa and West Asia regional specifications. Israel's STI ecosystem is unique in its rapid evolution with the implementation steps taken by the government and industry in Israel. Moreover, Israel is one	1. **Administrative support:** The Israeli government is significant in supporting Technology Transfer initiatives. Programs and organizations such as the Israel Innovation Authority (formerly the Office of the Chief Scientist), grants, and tax incentives stimulate knowledge transfer. 2. **Strong Industry-Academia Collaboration:** Israeli universities have developed interconnected relationships with industries and work in close connection with each other. This is highlighted in its 3rd global ranking in terms of university-industry linkages for	**Government:** • Israel Innovation Authority (IIA) for Industrial R&D **Industry:** • Lucid Logix Technologies Ltd. • BioRap Technologies Ltd. • BIRAD- Research & Development Co. Ltd. • Yeda Research &

	of the largest GERD contributors of more than 4%. The R&D ecosystem of Israel is founded on three pillars - basic scientific research conducted in universities, research undertaken in government institutions and research undertaken by the industrial-civil collaborations. The private sector of Israel also pitched in extensively with their investments towards R&D since 2000, reducing the burden on the Government. The study of the Israeli innovation ecosystem will give us inputs on the key attributes required for spurring innovation in the country and how to stimulate industry and market-oriented research and innovation. Details of Israel innovation ecosystem is provided in Annexure II (d)	R&D. The connectedness between industry and academia contributes to an enhanced Technology Transfer ecosystem in Israel. 3. **Establishment of Technological Innovation Hubs:** Israel has several innovation hubs and science parks that serve as vibrant ecosystems for Technology Transfer and entrepreneurship. Prominent examples include the Tel Aviv and Haifa high-tech clusters, which attract startups, investors, and multinational companies, fostering collaboration and knowledge sharing. 4. **Strong entrepreneurial culture:** Israel has a renowned entrepreneurial culture and a "startup nation" mindset. The society encourages risk-taking, innovation, and the commercialization of research outcomes. Israel also has a highly skilled workforce, including scientists, engineers, and entrepreneurs, who contribute to the success of Technology Transfer initiatives.	Development Company Ltd. **Academia and Research Institutes:** • Weizmann Institute of Science • Technion - Israel Institute of Technology • Tel Aviv University • Israel Institute for Biological Research • Agricultural Research Organization **Intermediary System** • International Collaboration Division (ICD) • Israel Tech Transfer Organisation (ITTN) • Incubators and Accelerators • Innovation Hubs
4.	**<u>South Korea</u>** S. Korea is the 6th ranked innovation country in the world and 1st amongst the South East Asia regional specification as per GII Report 2022. S. Korea has a legislative and government system for promoting government, industry and academia ties, especially for Technology Transfer. In addition, it has the	1. **Legislative and administrative support:** The Ministry of Science and ICT and the Korea Institute of Science and Technology (KIST) provide funding, policy support, and infrastructure for Technology Transfer and commercialization. It has set national R&D plans and strategies released every five years to align with changing trajectories and national priorities. These plans guide R&D investments, technology development, and Technology Transfer efforts, fostering innovation and economic growth.	**Government:** • National Science and Technology Council (NSTC) • National Research Foundation (NRF) • Korea Research Council of Industrial Science and Technology (ISTK) • Ministry of Science and ICT

	largest GERD contribution to national GDP. South Korea is one of the richest and most technologically advanced countries in the world, and this transformation was brought by emphasising education, research, sustained industrial development through innovation and engaging in global competitions. The education, science, R&D and innovation ecosystem is highly organized and governed by different ministries and other organizations. The Korean government is a big promoter of industrially relevant and collaborative research activities supported by technology collaboration and Technology Transfer. To uphold its stance towards collaborative and industrially relevant R&D, the government has introduced and enforced several Ácts and Laws', recognized as the backbone of a robust system consisting of various programmes and schemes introduced for promoting industry-oriented R&D in S. Korea. Details of South Korea innovation ecosystem is provided in Annexure II (e)	2. **Support organizations:** South Korea has established a vast network of support organizations facilitating Technology Transfer. These organizations, such as the Korea Technology Transfer Center (KTTC) and the Technology Commercialization Center (TCC), provide services like technology assessment, intellectual property management, market analysis, and business development support. 3. **Industry-Led R&D:** South Korea strongly emphasises industry-led research and development. Public funding programs, such as the Industrial Strategic Technology Development Program (ISTDP), support industry-led R&D projects, promoting Technology Transfer and commercialization aligned with industry needs. Indeed, the industry plays a significant role in leading R&D efforts in South Korea. The concept of chaebols, which are large, family-controlled conglomerates, has been instrumental in driving R&D consortiums and industry-led research initiatives in specific regions and domains. As one of the most prominent chaebols in South Korea, Samsung has established itself as a leader in R&D activities. With substantial resources and expertise, Samsung has developed its own research centres and innovation hubs, driving advancements in various sectors, including electronics, telecommunications, and information technology. These chaebols often collaborate with universities, research institutions, and government bodies to foster industry-academia partnerships and promote Technology Transfer. South Korea provides extensive support for startups and entrepreneurship. Initiatives like the Korea Innovation Center (KIC) and accelerators like the Korea Startup Factory nurture and mentor startups, providing funding, mentorship, and resources to facilitate Technology Transfer and the growth of innovative ventures.	**Industry:** • Samsung Electronics, South Korea • LG Electronics, South Korea • Hyundai Motor Co, South Korea **Academia and Research Institutes:** • Seoul National University, Seoul • Yonsei University, Seoul • Korea Advanced Institute of Science and Technology, Daejeon • Institute for Basic Science, Daejeon • Korea Institute of Oriental Medicine, Daejeon **Intermediary System:** • K-Startup Grand Challenge (KSGC) • Seoul Global Startup Center • SparkLabs • Osong Bio-health Science Park • High Tech IT Complex • Regional Specialized IT Clusters

5.	**<u>Germany</u>** Germany is the 8th-ranked innovation country in the world and ranked 2nd in terms of R&D investors. Germany is known for its speedy innovations and is one of the fastest innovation-evolving countries in the world. Through its pioneering and progressive R&D and innovation ecosystem, Germany prides itself in an outstanding global reputation. It owes this to the extensive research undertaken by the industrial sector, universities and research institutions with specific themes oriented towards the future. Germany has developed a sound innovation ecosystem, and establishing Fraunhofer institutes has played a significant role in reinvigorating its technology development and Technology Transfer ecosystem. The 72 Fraunhofer institutes can act as a role model for learning to enhance the Technology Transfer ecosystem in the institutes. Moreover, India has developed robust bilateral and multilateral engagements with Germany and established the Fraunhofer India Institute. Study of the German innovation	1. **Establishment of dedicated institutes to facilitate TT**: Germany is renowned for its network of Fraunhofer Institutes, which are dedicated to applied research and Technology Transfer. These institutes bridge the gap between academia and industry, focusing on industry-oriented R&D projects, technology development, and innovation transfer. Their close collaboration with industry partners facilitates the practical application of research outcomes. 2. **Germany's Mittelstand:** Mittelstands are small and medium-sized enterprises (SMEs) that form the backbone of the country's economy. These SMEs are often highly innovative and specialize in niche areas. The Technology Transfer ecosystem in Germany recognizes the importance of Mittelstand companies, providing support and resources to foster innovation, technology adoption, and transfer within this sector. 3. Establishment of **Technology and Innovation Hubs:** Germany hosts several technology and innovation hubs, such as the Silicon Saxony in Dresden, the Cyber Valley in Stuttgart-Tübingen, and the Research Campus in Garching. These hubs bring together researchers, startups, industry leaders, and investors, creating vibrant ecosystems that facilitate Technology Transfer, collaboration, and entrepreneurship. 4. **Government support Programs**: High-Tech Strategy, the German Research Foundation (DFG), and the Federal Ministry of Education and Research (BMBF) provide financial support to research institutions, startups, and innovative projects, fostering Technology Transfer and innovation.	**Government:** • European Social Fund (ESF) • German Federation of Industrial Research (AiF) • Federal Ministry of Education and Research (BMBF) • Federal Ministry of Economic Affairs and Energy (BMWi) **Industry:** • Volkswagen AG • Mercedes-Benz Group AG (former Daimler AG) • Robert Bosch • Siemens • Boehringer Sohn **Academia and Research Institutes:** • Mannheim University of Applied Sciences, Mannheim, Germany • Technical University of Munich, Munich, Germany • Friedrich–Alexander - University of Erlangen–Nuremberg, Germany • Max Planck Institute for

	ecosystem provides insights into stimulating innovation and the Technology Transfer ecosystem. Details of Germany innovation ecosystem is provided in Annexure II (f)		Informatics, Saarbrücken, Germany • Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute, Berlin, Germany **Intermediary organisations:** • Research Campus • Start-ups from Science (Existenzgründungen aus der Wissenschaft) - EXIST • Helmholtz Association • Max Planck Society • Fraunhofer Society

These countries have well-established networks of knowledge intermediaries, facilitating knowledge transfer from generators to consumers. The USA has Technology Transfer offices and industry-academia-government consortiums, Switzerland emphasizes linkages between actors, Germany established Fraunhofer institutes to promote industry-led R&D, and South Korea has a vast network of support organizations aligning industry needs with national priorities. The successful integration of these factors contributes to knowledge generation and conversion into market-oriented technologies, driving innovation in these countries.

4.3 Best practices Framework and point of Divergence from National TT ecosystem

The Best practicess in Technology Transfer have been identified and documented for each country, along with a snapshot of their respective Technology Transfer ecosystems, as outlined in Annexure II. As well as Indian Innovation ecosystem is documentation Annexure-II (a). The following critical best practicess in Technology Transfer are highlighted in Table 10 below in comparison to the technology transfer practices in India.

Table 10: Key best practicess in technology transfer in select five international countries in comparison to the technology transfer practices in INDIA

Table 10 (a): Governance Practices:

- Legislative law and administrative framework for promoting Technology Transfer as an activity in the country
- Setting up a dedicated entity for Technology Transfer and sufficient resources devoted to Technology Transfer by the institute with flexible and efficient institute administrators

Sr. No.	Name of Country and their governance practices		Indian Practice	Remarks
1.	**USA**	Key legislative frameworks for promotion of technology transfer and bringing the required impetus to technology transfer are established in the USA are as follows: • Stevenson-Wydler Technology Innovation Act of 1980; • Bayh-Dole Act of 1980 - 35 USC 200; • Federal Technology Transfer Act (FTTA) of 1986 - 15 USC 3710; • The National Competitiveness\ Technology Transfer Act, 1989 Dedicated entities are established for Technology Transfer at the national level and institute level. Most of the universities have created their own Technology Transfer Offices (TTOs) with different structures based on centralised or decentralised approaches.	India has enacted policy measures to facilitate technology transfer, encourage innovation, and promote collaboration between academia, research institutions, and industries through the following measures: • Science, Technology, and Innovation (STI) Policy (2013) • Patents (Amendment) Rules (2020) • National Biotechnology Development Strategy (2015-2020) Organizations such as CSIR, ICAR have developed their own guidelines for Transfer of	The establishmet of TTOs in India is still evolving, and many of them are formed as separate entities or sister arms of technology or innovation-focused entities in the organization and are bound by the financial and administrative structure of the host institutions. There is a need for apex-level policy and guidance to steer the development of this function through

2.	**Switzerland**	The **Federal Act on the Promotion of Research and Innovation (RIPA)** contains the primary regulations and statutes governing technology transfer in the country. At the national level, academic research institutes and universities in Switzerland collaborated to create a professional organization that is known as the **swiTT (Swiss Technology Transfer) Association which** encourages both collaborative efforts with the private sector as well as the business development of new technologies.	Technology, followed across their ecosystem of multiple laboratories and business development teams. Prominent academic and R&D institutes such as IITs have also developed their own guidelines for Licensing of Technology developed within their institutions. The governance model for technology transfer in India involves multiple stakeholders, including government bodies, academic institutions, research organizations, and industry players. Some of the government entities that are playing significant role in technology transfer are listed below: • **Technology Development Board (TDB)** • DST, GoI has created **'Technology Enabling Centres (TEC)'** • DST is also creating '**Technology Innovation Hubs'** • The **Department for Promotion of**	comprehensive legislation, policy-making, establishment and operational guidelines. • It also reported in the present study that 96% of TTOs The study mentioned that TT guidelines followed are part of the IP policy of their respective host institution, but they do not have any dedicated legislative act or policy at the national level.
3.	**Israel**	The R&D law of 1984 brought up the importance of industry investing in national R&D. Israel education and research institutes have established TTC as a company and not an office within the University (TTO), which are wholly owned University subsidiary with a business focus		
4.	**Germany**	Germany has enacted the **Employee Invention Act** (GesetzüberArbeitnehmererfindungen). Under this Act, Patent Exploitation Agencies were established in universities, which were further connected with Technology Allianz to facilitate technology transfer. Germany is on its way to establishing a national entity 'The German Agency for Transfer and Innovation' to support and		

		facilitate technology transfer of technologies developed by universities and research institutes.	**Industry and Internal Trade (DPIIT)** under the Ministry of Commerce and Industry has established the "Cell for IPR Promotion and Management" (CIPAM) • **Council of Scientific and Industrial Research (CSIR):** • **Technology Transfer Offices (TTOs):** In HEL and NRLIn India, the absence of specific legislative norms dedicated to technology transfer is a notable gap in the current framework. Unlike some other countries, India does not have comprehensive legislation explicitly regulating and promoting technology transfer activities. Although at institute level technology transfer guidelines are implemented but no dedicated law or act for promoting technology transfer activities in the country.	
5.	**<u>S. Korea</u>**	South Korea has a legislative framework for promoting and stimulating TT-related activities. The key legislative norms and acts that regulated TT in the country are "TT and Commercialization Promotion Act", "The Invention Promotion Act", "The Industry Education Enhancement" and "Industry-Academia; The "Technology Transfer and Commercialization Promotion Act" Diverse structures are proposed to boost the ecosystem for TT such as Technology Licensing Offices and Technology Management Offices along with dedicated programs "Fostering Human Resources for the University-Industry Cooperation Program" and "Technology Support Program"		

Table 10 (b): **Organizational and Managerial Practices:** The key practices include: dedicated organizational structure; experienced leadership and management; multidisciplinary team composition; intellectual property management; technology evaluation and valuation, etc.				
Sr. No.	**Name of Country and their governance practices**		**Indian Practice**	**Remarks**
1.	**USA**	There are two fundamental models for administering licensing offices: centralization (institute level) and decentralization (department, laboratory or research group level) Further, TTOs established in the US system showcase well-defined organization and managerial practices led by the head and have set roles and responsibilities ranging from invention disclosure to IP protection to technology valuation and its management.	In India, TTOs vary in terms of their team competency and team members' roles. While some TTOs have well-defined teams that handle various activities associated with the Technology Transfer process, many TTOs lack a clearly defined team structure and require capacity building and training for their emerging Technology Transfer professionals. Nearly 60% of TTOs reported that they require practical experience in TT, such as IP management, Technology evaluation and assessment, project management, 'Know how' to develop and transfer technologies. The Indian technology transfer	Many TTOs lack clear team structures, requiring clarity of roles and responsibilities at each level of the TTO function. Theoretical learning also needs to be supplemented with practical TT experience in functions such as IP management and tech evaluation; hence, capacity-building programmes need to be integrated for efficient TTO functioning.
2.	**Switzerland**	Switzerland's TTOs have a well-organized approach to getting good ideas into the world. They work closely with the University /Institute's dedicated schools and companies to ensure inventions turn into useful products. Swiss TTOs are especially good at helping smart people protect their ideas with patents. They team up with local and international businesses to put these ideas to work, making Switzerland a hotspot for creative thinking. According to the swiTT, public research organizations in Switzerland have dedicated staff members engaged as full-time equivalents (FTE) specifically for technology transfer activity inside the organization or institute. swiTT itself is composed of dedicated TT professionals that extend TT activities for HEI in the public sector, medical field and NGOs to the private sector		

3.	**<u>Israel</u>**	TTOs in Israel are characterized by highly collaborative and agile organizational structures. They are closely integrated with universities and research institutions, fostering a culture of innovation. TTOs emphasize proactive engagement with industry partners, both domestic and international, and they excel in technology assessment and IP management. They often encourage entrepreneurship and facilitate the formation of startups based on academic research. These TTOs are known for their responsiveness and adaptability, swiftly navigating technology transfer processes and leveraging Israel's vibrant startup ecosystem for successful commercialization outcomes. One of the most successful TTO in Israel is the Technology Transfer Company of the Hebrew University (YISSUM) that has a fully functional team with effective leadership and governance and a set of different functions ranging from IP protection to technology management.	ecosystem encompasses a range of organizations and practices aimed at facilitating the transfer of technology and knowledge from research and academic institutions to industry and the broader economy. Some key practices are as follows: • Many academic and research institutions in India have set up dedicated TTOs to manage technology transfer activities, such as IIT-Madras. • Some TTOs in India work closely with incubators and accelerators to support startups and entrepreneurs in commercializing technologies such as IIT-Ropar's AwaDH. • Most of the TTOs in India assist in filing patent applications for promising inventions and	
4.	**<u>Germany</u>**	TTO in Germany are characterized by several key elements such as close collaboration with universities and research institutions; structured intellectual property management; undertaking technology assessment and evaluation and providing licensing and spin-off support along with funding and grants. Some of the key TTOs also provide required training and education to researchers, helping them understand the		

		commercialization process, IP rights, and entrepreneurship. They may offer workshops and seminars to foster an entrepreneurial mindset. TTOs in Germany are essential intermediaries between academia and industry, working to bridge the gap between research and commercialization. For example, TTO, as set up as part of the HELMHOLTZ ASSOCIATION, has established its dedicated technology transfer units across research centres to act as independent entities with a mandate to create profit from the knowledge and technology generated through the characteristics mentioned above TTOs are run by teams with well-defined roles and responsibilities.	innovations. They work with patent attorneys or agents to secure intellectual property rights. In addition, technology scouting and outreach activities collectively contribute to the growth and development of India's technology transfer ecosystem, supporting innovation entrepreneurs hip.	
5.	**<u>S. Korea</u>**	TTOs established in S. Korea universities and research institutes have well managed team with set of responsibilities which are monitored and reported as per the national S&T indicators. These TTOs follow set indicators for the technology listing, deployment and commercialisation and accordingly build their data.		

Table 10 (c): Financial Sourcing and Administration Practices: Dedicated financial resources should be allocated to the TTO and different routes for financial support should be explored by the TTO, such as venture and angel funds; CSR; Alumni funds etc. The financial governance in form Regular audits (focus on technical audits) is also key best practices of successful TTOs.

Sr.No.	Name of Country and their governance practices		Indian Practice	Remarks
1.	**USA**	The TTOs established in the countries are financially supported by the government or dedicated research/innovative entities in the countries and are also evolved to be self-sustainable and report profits in high numbers. There are some common audit practices followed by TTOs that include financial audit, compliance audit, IP audit and technical audit and risk assessment as carried out in Technology Transfer Office, University of California and Berkeley. The audit practices of individual TTOs in the USA may vary based on the specific institution and its policies.	• Financial resources for technology transfer in India come majorly from government funding. • In India, while TTOs have been established, there is a lack of central-level programs dedicated to supporting Technology Transfer activities, with only a few programs such as those initiated by the Biotechnology Industry Research Assistance Council (BIRAC). • It has been identified through this study that less than 1% of TTOs have been financially sustainable, and through the present study, 36% of TTOs reported that they need financial support to cater to various stages of the TT process	The TT ecosystem in the country is still evolving and requires dedicated financial support to facilitate its functioning and development. Establishing robust financial governance mechanisms is crucial to ensure transparency, accountability, and effective utilization of funds within TTOs. Clear guidelines and protocols for financial management, budget allocation, and reporting are required to promote good governance practices and build stakeholder trust. Additionally, capacity-building initiatives and training
2.	**Switzerland**	The university and R&D community are encouraged and assisted in collaborating with the industry. • The TTOs are eligible for a fair financial share of the profits made by the collaboration partner. The share comes from the industry value of its innovation.		
3.	**Israel**	• This financial backing underscores Israel's proactive approach to bridging the gap between research and real-world applications, making it a global leader in innovation and technology commercialization. The Israel Innovation Authority has a $400 million budget		

		for Technology Transfer support programmes. • The R&D fund grants 40% of authorized R&D programme costs. Dedicated sources to support gap funding with a focus on accelerating Technology Transfer are in place (e.g. **National "Bridging the Gap" fund: KAMIN**	such as to boost TRL levels and covering background risks of technology adopter.	programs can enhance the financial management skills of TTO professionals, ensuring efficient utilization of funds and adherence to financial governance standards.
4.	**<u>Germany</u>**	The government has introduced several financial support programmes to enhance the Technology Transfer activities routed through the TTOs, for example - the Central Innovation Programme for SMEs (ZIM); Innovation Vouchers; Proof-of -Concept-Funding (VIP); Helmholtz Enterprise Fund and Helmholtz Validation Fund that provide substantial fund for Technology Transfer activities.		
5.	**<u>S. Korea</u>**	The government provides funding through a range of programs • TTOs in South Korea generate revenue through licensing agreements with industry partners. • Licensing revenue is often shared between the TTO and the inventors or research institutions. • TTOs sometimes take equity stakes in startup companies developing technologies based on research conducted at universities or institutions. • TTOs may receive philanthropic contributions from individuals, companies, or other organizations.		

Table 10 (d):Functional Practices Safeguard the organisational intellectual property; Technology assessment exercise; Technology Readiness Levels (TRLs); Technology valuation; Commercial potential exercise; Technical specificities; IP ownership (type of IP licensing); Negotiate Licensing agreements; Market the IP to private firms.				
Sr. No	**Name of Country and their governance practices**		**Indian Practice**	**Remarks**
1.	**<u>USA</u>**	Marketing the IP to private firms is the most prevalent practice in the US ecosystem, where linkages between industry and academia are quite productive. • TTOs have dedicated standard operating procedures and protocols allocated for different functions. • There are advanced management services for skilling TTO professionals, such as AUTM certificate in Technology Transfer. • Evaluation of the commercial potential of innovations forms the basis of the technology licensing, where the market potential and commercial utility and valuation is carried out by TTOs. • Negotiation of licensing agreements is one of the crucial activity and functional practices of TTOs as highlighted in the case studies.	In India, it is observed that many TTOs lack well-defined functions and require support in terms of capacity building to effectively undertake Technology Transfer activities. 68% of TTOs reported that they need support for technology development and validation.	TTOs in India and the select International countries share the goal of facilitating technology transfer, but they differ in functional aspects. The TTOs of select countries often benefit from more substantial funding, possess extensive expertise in intellectual property management, engage with a mature technology commercialization ecosystem and its associated functions, and have well-established collaborations with various industries. In contrast, Indian TTOs face budget constraints, varying levels of IP management expertise, an evolving technology commercialization
2.	**<u>Switzerland</u>**	TTOs established at universities and public research organizations undertake: • Research collaborations with innovation actors (manage contracts for the same). • IP protection and management • IP commercialization • Evaluation of commercialization potential • Few TTOs also provide mentoring for start-ups based on the knowledge and intellectual property generated by host organisations.		

3.	**<u>Israel</u>**	Most institutes and their TTOs in Israel are aggressive on IP filing and licensing in Israel. **E.g. Yissum** has created open-source platforms to promote IP sharing and licensing. TTOs negotiate and execute licensing agreements with industry partners to transfer technologies for commercialization. TTOs handle the following functions: • Negotiation of licensing terms, • Royalties • Intellectual property rights. • business plan development • market analysis • funding strategies • Connecting entrepreneurs with industry networks and investors		ecosystem, and distinct regulatory environments. Countries support startups and innovation, but the maturity of the ecosystem and the scale of operations vary, impacting the level of support provided to researchers and innovators.
4.	**<u>Germany</u>**	TTOs in Germany play a pivotal role in fostering innovation by concentrating on various strategic areas. They excel in technology transfer by harnessing the potential of contract research, forging strategic collaborations with key innovation stakeholders, and embracing the principles of Open Innovation as one of their core functional attributes. • For example, prestigious institutions like the Max Planck Society prioritize tasks that encompass comprehensive invention assessments, robust intellectual property protection, active marketing of intellectual property assets, fostering effective communication with industry partners, and guiding inventors in the process of forming their own companies based on research outcomes. This multifaceted approach underscores Germany's commitment to driving technology transfer and promoting a dynamic innovation ecosystem.		

5.	**<u>S. Korea</u>**	TTOs of S. Korea perform a range of tasks to facilitate technology transfer and commercialization: • Evaluate Commercial Potential: TTOs assess new technologies' commercial viability and their licensing potential. This involves researching technology demand and identifying industry partners. • Intellectual Property Management: They identify patentable technology, manage patent applications, and oversee the licensing of intellectual property owned by universities and research institutions to commercial partners. • Business Development: TTOs actively recruit industry partners and negotiate licensing or Technology Transfer (TT) agreements. This includes participating in industry conferences, networking events, and establishing industry partnerships. • Support Startup Creation: TTOs assist innovators and researchers in establishing their own companies to bring their technology to market. This support includes mentoring, business planning, and helping secure funding. • Training and Education: TTOs train researchers and students in various aspects of technology transfer. This includes workshops, seminars, and training programs on intellectual property management, licensing, and entrepreneurship. These tasks collectively enable TTOs to bridge the gap between research and commercialization, fostering innovation and economic growth.		

Table 10 (e):Output / Reporting Practice: Documented Output of TTO: Licences; Royalties; Patents; sponsored research agreements; start-up companies; invention disclosures; Students; informal transfer of know-how; Product development				
Sr. No.	**Name of Country and their governance practices**		**Indian Practice**	**Remarks**
1.	**USA**	• TTOs report their outcomes in their reports. • AUTM releases specific rankings and a performance review of the TTOs. • TTOs have diverse reporting relationships, degrees of autonomy, and resource commitments.	In India, it is noted that there is a lack of standardized evaluation and reporting activities in TTOs. TTOs in India often follow their own norms for reporting and performance assessment. 64% of TTOs reported that audit and regular reporting of TT activities is majorly a part of the host institution's annual assessment reporting and audits.	Differences in monitoring and performance evaluation at the institutional level and gaps in the reporting framework make it difficult to measure and compare the efficiency of TT performance at the ecosystem level. National and international benchmarking can accelerate the development of the Indian TT ecosystem through the potential sharing of best practicess and cross-learning. Developing standardized guidelines for evaluating and reporting Technology Transfer Offices (TTOs) is crucial for ensuring transparency accountability and
2.	**Switzerland**	swiTT maintains a database of technology and licensing opportunities from public research and education institutions. A User-friendly portal exists to scout the technologies (https://switt.ch/swiss-technology-transfer)		
3.	**Israel**	TTOs in Israel engage in several activities to track and report on their technology transfer efforts that includes: • Intellectual Property (IP) Portfolio Management • Licensing Activities • Technology Transfer Metrics • Economic Impact By implementing robust output and reporting practices, TTOs in Israel provide stakeholders, including researchers, investors, industry partners, and funding agencies, with transparent and comprehensive information about their technology transfer activities. The output and reports are presented on TTO's websites.		
4.	**Germany**	Each TTO in universities and public research organizations; Technology Alliance, and Independent tech transfer units set up by research associations have developed websites and annually showcase the IP and technology transfer details.		

		Reporting in annual Reports is mandatory for reporting R&D inputs and outputs generated through Germany's R&D and innovation policy.		continuous improvement in their operations.
5.	**<u>S. Korea</u>**	TTOs publish their initiatives and results in studies which describe licensed or commercialized innovations, their revenue, and TT's economic and social effects. South Korean universities and research organizations publish annual research, cooperation, and TT reports. TT impact paper records social, economic, and environmental impacts. covering aspects such as job creation, money production, product and service development, and TT's larger social advantages. Surveys and comments can promote TT and identify investment and partnership opportunities.		

Table 10(f):Incentivizing Practices: Motivate scientists/ faculty/ researchers/industry/startups to develop technology and undertake the TT process				
Sr. No	**Name of Country and their governance practices**		**Indian Practice**	**Remarks**
1.	**USA**	Increased royalty shares, counting tech transfer participation in tenure and promotion decisions, and Technology Transfer awards for academics are some examples of the many ways American colleges have experimented with incentivizing academics to participate in Technology Transfer.	• In India, there are relatively fewer incentivizing mechanisms for Technology Transfer than in other countries. • The introduction of the Patent Box regime aimed to incentivize Technology Transfer by providing tax benefits for income derived from patents; its effectiveness in India has been limited so far. • Institutes have designed their own incentive structures to reward researchers for their involvement in technology transfer at the institutional level. There are no other	Currently, there are limited specific incentives available for TTOs in India. A robust and rewarding multi-tier incentive structure that recognizes and motivates the role of each stakeholder in successful TT operations is required. As seen in the top-performing TT ecosystems, well-defined incentives for the industry, institutions and innovators are required to effectively channel the available resources. • To strengthen the technology transfer ecosystem, the following gaps are identified: Improving tax benefits under the Patent Box regime to encourage Technology Transfer. • Introducing financial (grants, tax credits) and non-financial (IP support) incentives for TTOs. • Allocating funding for various
2.	**Switzerland**	The annual survey is conducted, and institutes with superior Technology Transfer are acknowledged and financially rewarded for their achievements.		
3.	**Israel**	Tax benefits; Feed-in-tariffs (FIT) scheme was initiated by the government for the promotion of uptake of renewable and low-carbon electricity generation; grants/project financing from different governmental agencies for undertaking successful Technology Transfer.		
4.	**Germany**	In the case of German Universities: Patenting as one criterion for faculty promotion and its tenure. Incentives are available for companies on public procurement of technologies, such as introducing the 'Centre of Excellence awards' through the **Centre of Excellence for Innovative**		

		Procurement (KOINNO).	explicit incentivising mechanisms.	technology transfer stages to strengthen the institutional ecosystem. • Facilitating joint funding programs between TTOs and industries to spur innovation.
5.	**<u>S. Korea</u>**	Tax incentives and reductions encourage TT between enterprises to improve technical skills and capital recovery in technology development. SMEs and some medium-sized firms pay 50% less corporate income tax on patent transfers to Korean nationals.		

Table 10 (g):Linkages and Network - Oriented Practices Effective interface/portal /technology display /exhibitions				
Sr. No	**Name of Country and their governance practices**		**Indian Practice**	**Remarks**
1.	**USA**	Many universities have Innovation Corps (I-Corps™) programmes supported by NSF (National Science Foundation) that encourage researchers to engage in commercialization.	63 % of TTOs reported difficulties in Industry outreach and found lack of trust, expectation mismatch, and rigidness as key hurdles in strengthening the IA interlinkage. Some key network-oriented practices that are followed to strengthen technology transfer in India: 1. **Innovation Hubs and Clusters**: Innovation hubs and clusters in India bring together research institutions, start-ups, industries, and investors in a shared physical space. These hubs facilitate networking, idea exchange, and collaborative projects that can accelerate technology transfer. 2. **Technology Showcases and Exhibitions**: The showcase of innovative technologies through exhibitions and technology showcases are some emerging practices to strengthen the networking for the TT ecosystem that allows researchers to connect with potential licensees, investors, and industry representatives.	
2.	**Switzerland**	• Each consortium for Technology Transfer, institute, and university has created effective website portals/tabs showcasing the developed and transferable technologies. • swiTT facilitates and strengthens cooperation as well as technology flow to and forth between industry and research organisation of Swiss in the public domain.		
3.	**Israel**	In each collaboration for technology transfer, institutes and universities have developed effective website portals/tabs displaying the technology developed and available for licensing and transfer.		
4.	**Germany**	The TTOs established in Germany, especially in universities linked through Technology Allianz and independent units set up by research institutes/ associations, focus on networking through the following means: • Formation of sector-specific technology groups/network working groups • Workshops and thematic interactions with Industry • Open Innovation Workshop • Partnering events and showcase events The other facilitators of the ecosystem also play an important role in facilitating the technology process. Such facilitators in Germany that play		

		an essential role are as follows: • Common Labs • Commercial arms • Incubator on campus • Research Centres, e.g., Helmholtz research centres. Technologies Allianz is a German network of patent marketing and tech transfer agencies.	3. **Incubators and Accelerators:** Technology-focused incubators such as TBI provide a supportive environment for start-ups to develop and commercialize their technologies. These programs offer mentorship, funding, and networking opportunities. 4. **Industry Associations and Clusters**: In India industry associations through CII related to the sector in which the technology operates helps to boost linkages. These platforms provide opportunities to connect with industry leaders and potential partners.	
5.	**S. Korea**	In South Korea, industry-academia collaboration is often facilitated through government initiatives such as the **Industry-University Cooperation program**, which provides funding and resources to support joint research projects between universities and industry partners.		

OPERATIONAL MODEL

5. Operational Model

Chapter 5 describes an operational model for technology transfer that outlines the systematic approach and processes involved in transferring technology, knowledge, or intellectual property from one entity to another. Creating an effective operational model for technology transfer involves defining the processes, roles, and activities. The model helps ensure that the transfer is successful, efficient, and aligned with the goals of both parties. Based on the desk research of the five international ecosystems studied and the TT models available in the literature, a comparison was drawn with the current operational practices in the Indian TT ecosystem to identify gaps. The findings have been summarized and presented as a suggestive operational model for the Indian TTOs and TTCs.

Section 5.1 provides the list of TT processes, and section 5.2 provides the list of roles and activities to be carried out by TTO staff.

5.1 TTO's Process

Listed below are the activities and a brief description, which must be carried out in the sequence given below for an effective Technology Transfer between two entities.

1. Identification and Selection of Technology: The process begins with steps to identify and select the technology, innovation, or intellectual property suitable for transfer. This involves assessing the problem addressed by the innovation, potential market value, relevance, and the readiness of the technology for transfer.

2. Protection of Intellectual Property: Before any transfer occurs, protecting the intellectual property (IP) rights associated with the technology is crucial. This may involve patents, copyrights, trademarks, or other legal protections to prevent unauthorized use or reproduction.

3. Market Assessment: A comprehensive market analysis helps understand the technology's demand, competition, and potential applications. This step helps determine the technology's commercial viability and is an important precursor to valuation and negotiation.

4. Technology Valuation: Assign a monetary value to the technology based on market potential, competitive advantages, and expected returns. The valuation is important for negotiation and determining the terms of the transfer and can be effectively carried out based on the outcome of market assessment.

5. Negotiation and Agreement: Parties involved negotiate the terms of the technology transfer, including licensing agreements, royalties, equity stakes, or any other financial arrangements. Legal contracts are drawn up to formalize the agreement.

6. Technology Packaging and Documentation: Prepare all necessary documentation, technical specifications, and user manuals to facilitate the effective transfer of the technology. The documentation should be clear and comprehensive.

7. Training and Skill Transfer: If applicable, training and knowledge transfer may be provided to the receiving party to ensure they can effectively utilize and maintain the technology.

8. Quality Assurance: Define and develop basic quality control measures that have to be implemented to ensure the technology meets agreed-upon standards and specifications during the transfer process.

9. Testing and Validation: Define and develop procedures to conduct tests and validation to confirm that the technology functions as intended and meets the required performance standards.
10. Deployment and Integration: Assist the receiving party in integrating the technology into their operations or products. This may involve providing technical support and troubleshooting.

11. Monitoring and Support: Continuously monitor the technology's performance and provide ongoing support and maintenance as needed. Address any issues or challenges that may arise.

12. Feedback and Improvement: Encourage feedback from the receiving party to identify areas for improvement in the technology or the transfer process itself. Use this feedback to enhance future transfers.

13. Commercialization and Marketing: If the technology has commercial potential, support the receiving party in marketing and promoting the technology to target customers or industries.

14. Performance Evaluation: Evaluate the success of the technology transfer based on predefined metrics, including financial returns, market penetration, and user satisfaction.

15. Renewal or Termination: Depending on the terms of the agreement, assess whether to renew, terminate, or renegotiate the technology transfer arrangement.

16. Legal Compliance: Ensure all transfer aspects comply with relevant laws, regulations, and contractual obligations.

5.2 Roles and activities to be carried by TTO staff

Technology Transfer Office (TTO) staff play a crucial role in facilitating technology and knowledge transfer from academic and research institutions to the commercial sector. They are the intermediaries that help bridge the gap between research and commercialization. Their responsibilities encompass a wide range of activities aimed at protecting intellectual property, fostering collaborations with industry, ensuring that innovations reach the market, and ensuring that innovations benefit society and the economy.

The key roles and activities should be performed by TTO staff.

1. Intellectual Property Management:

- **Technology Assessment:** TTO staff evaluate the commercial potential of inventions and innovations generated within the institution. They assess factors like novelty, market demand, and patentability.
- **Patent Filings:** TTO staff work on patent applications for promising inventions, coordinating with patent attorneys or agents to secure intellectual property rights**.**
- **Intellectual Property Protection:** They ensure that intellectual property rights, such as patents, trademarks, and copyrights, are protected and maintained.

2. Licensing and Commercialization:

- **Licensing Negotiations:** TTO staff negotiate licensing agreements with external parties, including companies and startups interested in using the institution's technologies.
- **Start-up Incubation:** They may support the formation of spin-off companies or startups based on institution-developed technologies, assisting with business development, funding, and mentorship.
- **Technology Marketing:** TTO staff actively promote the institution's technologies and innovations to potential licensees and investors.

3. Industry Engagement:

- **Industry Partnerships:** They establish and maintain relationships with industry partners, facilitating collaborations, research agreements, and sponsored research projects.
- **Technology Matchmaking**: TTO staff connect researchers with industry partners seeking specific expertise or technologies.

4. Funding and Grants:

- **Identifying Funding Opportunities:** They can assist researchers in identifying funding opportunities for technology development, including government grants, private investment, and venture capital.
- **Grant Proposal Support:** TTO staff may help researchers prepare and submit grant proposals to secure project funding.

5. Education and Training:

- **Awareness Programs:** They can organize workshops, seminars, and training sessions to educate researchers and faculty about technology transfer processes and best practices.

6. Compliance and Legal Matters:

- **Compliance Oversight:** TTO staff ensure that technology transfer activities comply with relevant laws, regulations, and institutional policies.
- **Conflict of Interest Management:** They can manage and mitigate conflicts of interest in technology transfer transactions.

7. Administrative Functions:

- **Record Keeping:** TTO staff maintain comprehensive records of all technology transfer activities, including agreements, patents, and licenses.
- **Budget Management:** They may manage the budget for technology transfer operations, including staff salaries and other expenses.

8. Market Research:

- **Market Analysis:** TTO staff conduct market research to identify potential markets and applications for institution-developed technologies.

9. Outreach and Communication:

- **Stakeholder Engagement:** They engage with various stakeholders, including faculty, researchers, industry partners, and investors, to build and maintain relationships.
- **Reporting:** TTO staff may prepare reports and presentations to update institutional leadership on technology transfer activities and achievements.

10. Policy Development:

- **Policy Advocacy:** They may contribute to developing institutional policies and strategies for technology transfer and commercialization.

While several working arrangements related to the structuring and establishment of TTOs are in practice globally, as per AUTM, most successful TTOs have elements of the management structure as presented in Figure 15 (AUTM, 2006).

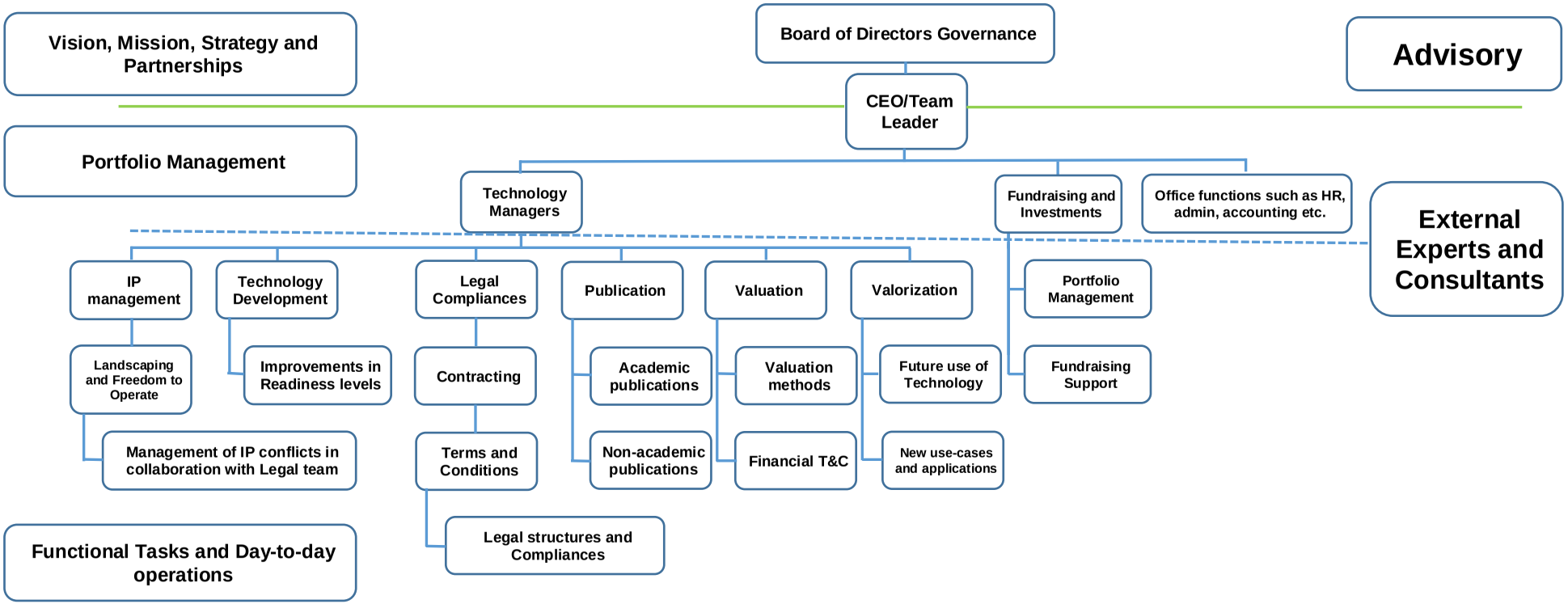

Figure 15: Management Structure

RECOMMENDATIONS AND WAY FORWARD

5. Recommendations and Way forward

Building a robust technology transfer ecosystem in India is crucial for driving innovation, economic growth, and competitiveness. These recommendations aim to create an enabling environment where technology transfer can thrive, fostering innovation, economic growth, and the sustainable development of India's knowledge-based economy. Successful technology transfer ecosystems require collaboration among government agencies, research institutions, industry stakeholders, and entrepreneurs to achieve their full potential.

Following are a few key recommendations for enhancing the technology transfer ecosystem within India.

1. **Development of a comprehensive policy ecosystem for Technology Transfer:**
   As evident from the study of the international TT ecosystemspolicy documents, operational guidelines covering establishing and functioning TTOs, financial accounting and audit requirements specifically suited to innovation and technology transfer function, incentive stimulus and effective monitoring, evaluation and periodic policy review and revision mechanisms.These will serve a much-needed purpose to standardize fundamental concepts, documentation and reporting requirements and propel industry-academia relations to the next levels of maturity, trust and transactions. The TTOs can only have the functional autonomy and agility to succeed in the fast-paced technology environment through well-defined guidance.

2. **Training and Capacity Development:**
   High-quality training and professionalism are important to facilitate trans-disciplinary activities such as technology assessments, techno-economic evaluations, valuations, gap funding, technology development, upgrades, spin-offs and product development.
   While international certifications are available in the country, they are not a replacement for foundational training within the Indian context. Accessibility of such certifications could also be a challenge in some cases. Specific TT-focused programs to provide foundational-to-advanced training to aspiring TT professionals in the country would strengthen the technology transfer centre's functioning, output and outcomes and improve the industry's confidence in pursuing collaboration with institutes and research laboratories.

   - **Foundational training program** covering technology transfer and commercialization concepts
   - **Awareness program** - specific challenges associated with transferring and commercializing in new age sectors such as climate tech.
   - **Specialized training and capacity building** focussing on essential TT activities such as TRL upgrade, technology assessment, technology valuation, negotiations, deal design and drafting, record keeping and performance review.
   - TTOs have provided enthusiastic suggestions based on their training requirements (presented in section 4.1.12).

3. **Mentoring:**
   It was found in the study that there exists a wide range in the maturity level of TTOs. Some aspiring TTOs have just started and are still aligning the initial set of resources, while some other emerging TTOs have teams in place and have developed considerable inroads in their target industry segments. Some very well-developed TTOs with plans to reach international markets are also active in the country. Each one requires a different type of support and guidance. Therefore, a multi-tiered mentoring program is recommended to cater to the needs of aspiring, emerging, and developed TTOs. Such a program will facilitate the free exchange of best practicess and encourage peer-to-peer learning through the exchange of knowledge and experience.

4. **Forming functional linkages and effective networks:**
   As observed in the study of the developed international TT ecosystems policy forming functional linkages, effective networks, and partnerships within the industry-academia space is a continuous activity. The efforts in strengthening this relationship are channelled through multiple formal and informal channels. Some effective interventions are as follows:

   - Establish dedicated TTOs within universities, research institutions, and government agencies to facilitate technology commercialization, IP management, and industry partnerships as single contact points for TT-related activities.
   - Stronger networking of TTOs with Incubators and Accelerators to facilitate technology transfer through start-up entrepreneurs and provide mentoring, resources, and access to networks to Spin-offs.
   - Implement technology scout programs that identify promising technologies within research institutions and match them with potential industry partners or investors.
   - Develop a calendar for annual Networking and Knowledge events (based on themes such as technology transfer events, innovation showcases, and networking forums to connect innovators, investors, and industry leaders) in collaboration with carefully matched specific industry bodies and associations and for effective interaction.
   - Developing a platform/mechanism for peer-to-peer networking and knowledge exchange through a dedicated knowledge-sharing platform should be done.

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