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Technology Transfer in Higher Education

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List of Figures and Tables

Acronyms

TT	Technology Transfer
TTO	Technology Transfer Office
HEI	Higher Education Institution
TTE	Technology transfer ecosystem
HE	Higher Education
R&D	Research and Development
IP	Intellectual Property
TM	Third mission
S3	Smart Specialisation Strategies
R&D&I	Research and Development and Innovation
SME	Small and Medium- sized Enterprise
PR	Public Relation
Uni	University

Abstract

The integration of technology transfer in higher education has emerged as a crucial conduit for the proliferation of knowledge and innovation. Delving into this importance, this study first embarks on a comprehensive literature review to unravel the quintessential role of research and development (R&D) in shaping university outcomes. Beyond the precincts of the university, the ecosystem development further encompasses stakeholders, individuals from higher education communities, and external partners. This extended ecosystem acts as a linchpin in the realm of university commercialization, forging productive partnerships, nurturing industry collaborations, and thereby casting a discernible socio-economic influence at the local level.

While a thriving R&D and an expansive ecosystem signal immediate success, they are not definitive harbingers of sustainable competitiveness in an unpredictable higher education landscape. Recognizing this, the research adopts a dual approach: amalgamating literature insights with empirical data, the latter gathered through a meticulous questionnaire survey. Business process modelling is utilized as a methodological tool to sculpt an adaptive framework tailored for technology transfer. Data from the Tetris[1] projects further enhance the study's empirical robustness, ensuring the model, though foundational, remains amenable to real-world adaptations. In summation, this thesis serves as a reference for higher education institutions, providing options for improving their technology transfer processes. By presenting an adaptable reference model and emphasizing the overarching ecosystem's role, the research equips universities and their partners to not merely excel today but to retain adaptability and competitiveness for the challenges of tomorrow.

[1] TETRIS - TECHNOLOGY TRANSFER INNOVATION SCHEMES IN LATIN AMERICA (618597-EPP-1-2020 -1-PT-EPPKA2-CBHE-JP

Thesis outline

Chapter 1: Introduction

This chapter introduces the study by establishing the importance of technology transfer (TT) within higher education institutions (HEIs) and its role in fostering knowledge dissemination, innovation, and socio-economic development. The research problem is articulated, along with the objectives of the study. A brief overview of the dissertation structure is also provided to guide the reader.

Chapter 2: Research Framework

In this chapter, the theoretical framework is established to ground the research. Key research questions are formulated, targeting gaps in the existing TT literature. The methodology is introduced, including the use of bibliometric analysis, data from the Tetris Project, and business process modeling. This approach integrates theoretical and empirical insights to support the development of adaptable TT models for HEIs.

Chapter 3: Research and Development (R&D) – Model/Type 1

This chapter focuses on the role of R&D within HEIs and how it aligns with the institutional mission to drive impactful research outcomes. The R&D-oriented model is explored through components like research strategy, innovation strategy, research management, and funding. Additionally, intellectual property (IP) management is discussed, including policies, patenting, and IP valorization. This model emphasizes strengthening internal research capabilities and creating pathways for the commercialization of research outputs.

Chapter 4: Ecosystem – Model/Type 2

Shifting focus to the external environment, this chapter examines the role of HEIs within a broader innovation ecosystem. The ecosystem-oriented model emphasizes open innovation and collaborative partnerships with industry, government, and community stakeholders. Key areas discussed include the support services offered by universities (e.g., licensing, commercialization, spin-off support), ecosystem connections, inclusiveness, and entrepreneurship. This model highlights the importance of building networks that facilitate technology transfer beyond academic boundaries.

Chapter 5: Changing Environment – Model/Type 3

Addressing the need for adaptability, this chapter examines the impact of global and societal challenges, such as climate change, sustainability, and evolving market demands, on TT processes. The adaptability-oriented model is introduced, emphasizing strategies that allow HEIs to remain resilient in the face of these challenges. Topics include aligning institutional incentives, building capacities, enhancing partnerships, effective IP management, and fostering an entrepreneurial culture. This model supports HEIs in adapting TT strategies to meet future societal needs.

Chapter 6: Assessment of Technology Transfer Maturity – Survey

This chapter provides a detailed overview of the survey methodology, which captures empirical data on the TT capabilities of different institutions. The survey is designed to assess institutional maturity across the three models (R&D, ecosystem, adaptability). Key survey areas include IP management, research activities, ecosystem engagement, and adaptability. The results are used to inform the development of a roadmap for institutions seeking to improve TT practices.

Chapter 7: Analysis of the Assessment Survey

Building on the survey data, this chapter presents an empirical analysis of TT practices across the sampled institutions. The results are mapped onto the three TT models, offering insights into the current state of TT within HEIs. This analysis highlights patterns, challenges, and areas where institutions excel or require improvement, ultimately informing model refinement and providing a comparative perspective on TT practices.

Chapter 8: Conclusion and Recommendations

The final chapter synthesizes the research findings and discusses the implications of the proposed TT models for HEIs. Recommendations are provided for implementing adaptable TT frameworks that align with institutional and environmental needs. Emphasis is placed on fostering resilience, sustainability, and collaboration in TT processes. The conclusion also addresses limitations of the study and suggests directions for future research.

Introduction

In the knowledge economy, the rapidly developing scientific and technical technologies and the accelerating process of economic globalization have made technological innovation and progress an important driver of economic growth. It is not only the invention or creation of innovative technologies that determines high economic growth but also, more importantly, the diffusion of new technologies so that they can be continuously disseminated and applied across economic and geographical space, becoming an important means of promoting industrial, technological progress (Hall, 2005). Technologies are vital for improving a country's economy, especially in growing countries, where a highly significant function is attributed to the industry's growth.

The function of higher education institutions has continued to step outside of tradition over time, transforming from institutions that initially provided education and teaching to open centres of learning and discovery. This has led to the transformation of higher education institutions from continuing education to places where new ideas are generated, i.e., the concept of the 'Modern University that has since emerged. HEIs have a crucial position in encouraging scientific and commercial collaboration in innovation systems around the world. Academics increasingly turn to technology transfer, knowledge exchange and research commercialization to ensure their work improves real lives. But more importantly, these life-changing inventions solve significant challenges facing the 21st century and create new products and markets of inestimable value to national and global economies. HEIs are pivotal and have a key position in encouraging innovation systems and business collaboration. The question arises of how establishing effective technology transfer mechanisms will challenge every HEIs. HEIs' technology transfer mechanisms will relate to various aspects such as university strategy, mission, ownership of intellectual property rights (e.g., the Bayh-Dole Act of 1980 in the U.S., which gave universities (and other nonprofit institutions) full ownership of inventions created by the academics they employ, was intended to address this issue), incentives for innovation, ecosystems, and adapting in a changing environment.

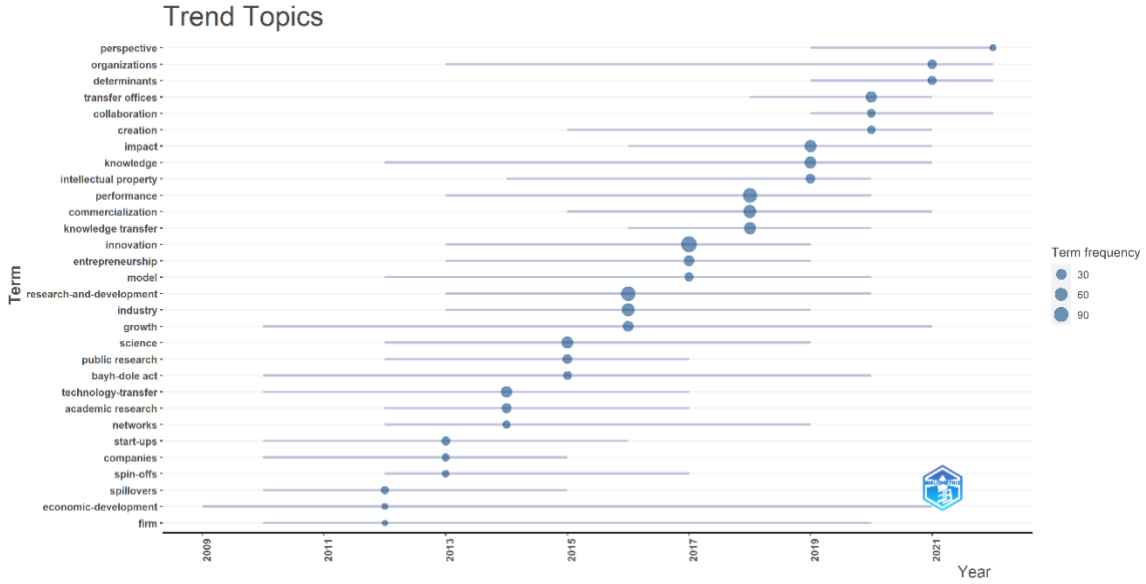
Technology transfer mainly refers to using innovative technologies, processes or applications of knowledge developed by another organization field (Rogers, 1995). The technology transfer office becomes an essential medium between HEIs and the business environment to facilitate the technology transfer process. On the one hand, establishing specialized technology transfer companies within universities can help develop relationships with the industry by reducing the critical information asymmetries typically encountered in the market for scientific knowledge.

On the other hand, the presence of technology transfer offices establishes competitiveness and reputational impact for HEIs.

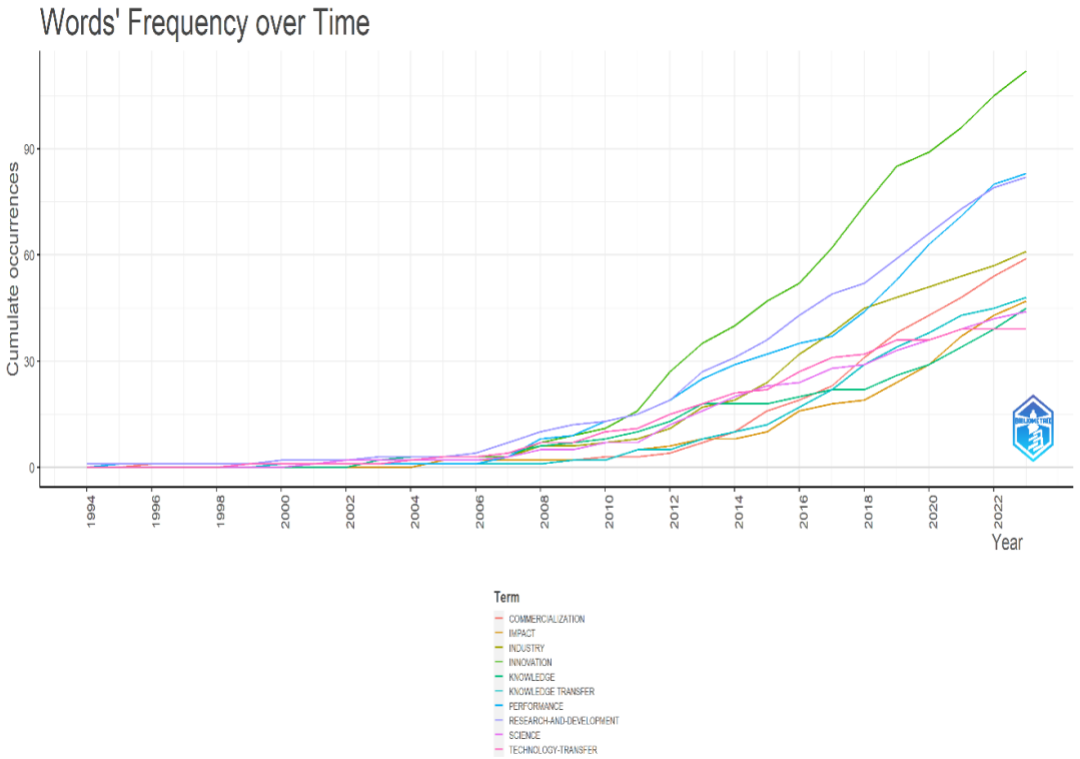
Most current studies in the literature refer to improving the efficiency of technology transfer, which is the general awareness and indicates that higher education aims to make a breakthrough in technology transfer development. For example, Kirby & El Hadidi (2019) argues that there is a need for greater collaboration between universities and businesses, and for broad national coordination policies to intervene that have helped higher education to achieve more technology transfer and commercialisation; González-Pernía et al., (2013) refers to more experience and teams of experts in technology transfer offices, as opposed to universities with clear academic entrepreneurship rules and higher patent records, are more likely to have effective university technology transfer results , mainly in terms of licensing and spin-off companies. The differential impact of regional context on university technology transfer spin-offs is also mentioned. Korff et al., (2014) argues that higher education should not only learn from past experiences, but also stresses that university management should maintain a level of transfer of organisational and personal experience (not only academic but also with industry) to learn from it. Technology transfer is not only a relationship between the university and industry, but also a link between the organisational and individual levels. Villani et al., (2017) argues that the success rate of university-industry collaboration is driven by certain characteristics of both parties and the TTO, including the relevant culture and characteristics, and that the TTO's intermediary coordination is important. Goble (2013) mentions that the characteristics of the technology transfer organisation (form of organisation, degree of autonomy, etc.) affect the effectiveness of collaboration with faculty, etc. and the effectiveness of invention disclosure. Siegel et al., (2007) mention the impact of regional policies on IP commercialisation and the importance of universities and regions developing and implementing coherent and viable technology transfer/commercialisation strategies, while the impact of the regional environment is also worth noting (Swamidass & Vulasa, 2009). For some organisations with short budgets and staff to secure patent applications and issue patents, technology marketing is sacrificed to the extent that potential collaborators are not found or it is difficult to bring the technology to market.

In addition to this, there are many related, although not universally relevant, studies that mostly focus on aspects of improving the benefits of commercialisation and on removing barriers to university-industry collaboration in order to improve the efficiency of technology transfer from universities. However, each university has its own characteristics and circumstances one size does not fit all, and not every university has the maturity and knowledge. Some universities are

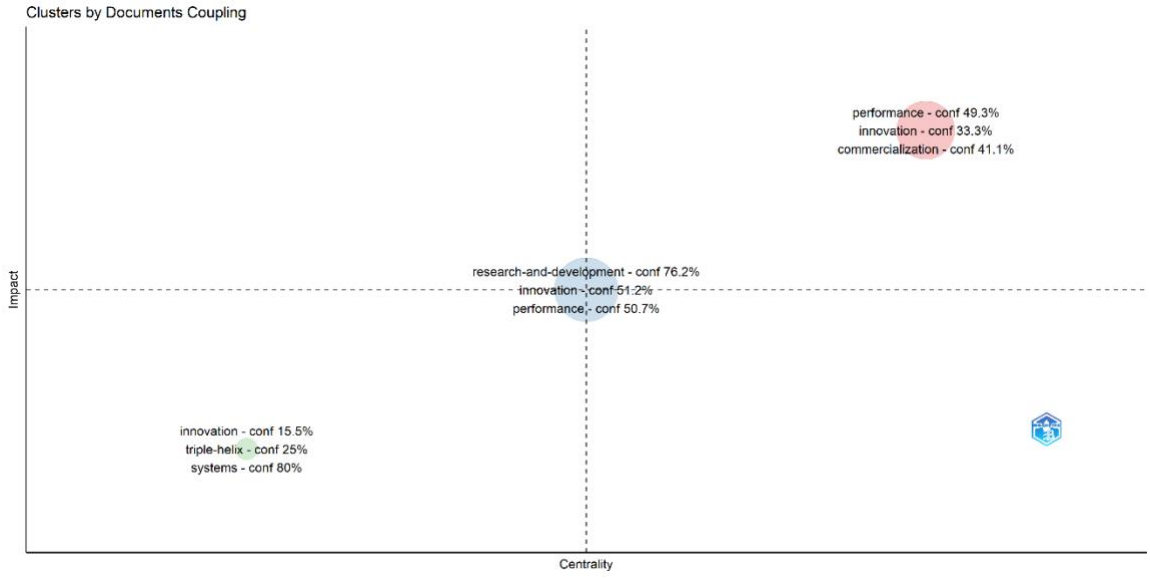
just starting out, while others are already playing a pivotal role in regional or national development. Institutions that need external support, or where the problem lies only in the linkages between universities and industry, in a sense imply that they are ripe for internal performance, or they are unaware of the internal problems and attribute the inefficiency of technology transfer to the linkages with external parties. Only a minority of the literature, noted the impact of strong or weak internal linkages. Beyond this, the literature seems to have neglected to consider how to stimulate the potential of higher education research and development, which is fundamental to improving the efficiency of technology transfer by generating a constant flow of innovation and invention.



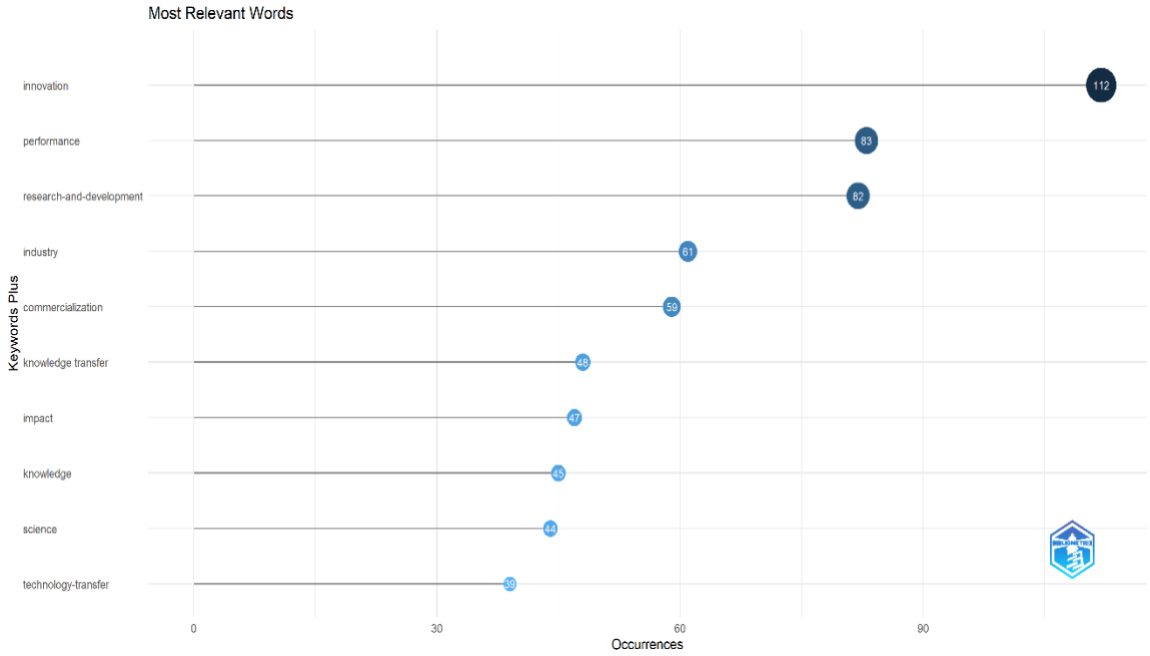
1. Figure Trend topics in HEI technology transfer



2. Figure Words' frequency in HEI technology transfer over time



3. Figure Word Clusters in HEI technology transfer until 2023



4. Figure Most relevant words in HEI technology transfer until 2023

Source: made by author

The evolution of technology transfer in Higher Education Institutions (HEIs) encapsulates the shift from isolated research and development to dynamic ecosystem engagement and adaptive responses to changing environments. Initially, the study by Audretsch et al. (2002) highlighted the foundational role of higher education institutions in regional development through knowledge spillovers, marking the genesis of academic interest in technology transfer. This foundational phase is where the institution accumulates knowledge and explores novel ideas and is supported by the increasing frequency of the term "research and development" in bibliometric analyses.

In terms of ecosystem engagement, Etzkowitz and Leydesdorff's (2000) 'triple helix' model emphasises the synergistic interactions between universities, industry and government, and promotes a collaborative approach to innovation. This view is visually confirmed by the density of interactions and thematic clustering in the bibliometric maps, which emphasise the centrality of 'ecosystem services' and 'partnerships' in research narratives, and the indispensable role of combining academic research with practical applications. The indispensable role of integrating academic research with practical applications is emphasised. Analysis of temporal trends shows a proliferation of themes related to 'research and development' and 'technology transfer', signalling a deeper engagement with the commercialisation of academic innovation.

This latest phase reflects the need for higher education institutions to adapt to a rapidly changing and fast-paced global environment. In this phase, technology transfer is not only

about innovation, but also about agility - responding to new market demands, evolving commercialisation strategies and fostering adaptive innovation pathways. This is exemplified by Shane's (2004) view of university derivatives as a vehicle for transforming academic research into economic assets. Visual data from the bibliometric analysis, particularly the increasing frequency of the term's 'commercialisation' and 'innovation', confirm this trend.

In summary, technology transfer within HEIs has indeed evolved in stages from a focus on R&D to actively shaping and participating in the innovation ecosystem to adapting to the changing global environment and market demands. This progression is consistent with the increasing complexity and interconnectedness of modern research fields, as described in the literature and visual data.

Therefore, in line with the bibliometric analysis, this thesis explores the establishment of effective technology transfer mechanisms in universities from the perspective of general relevance. The thesis proposes that universities are categorised into 3 models. Research and Innovation model, Ecosystem model and Environmental Change model. These three models may appear at any stage of technology transfer in universities (start-up, growth, maturity, and development), and provide a reference for problems that may arise in technology transfer in universities, or that some universities are working in this direction of technology transfer but do not know how to work on it, which can help universities to improve. These three mechanisms can exist independently or alternate in different stages, depending on the status and needs of technology transfer mechanisms in universities.

Research Framework

As this thesis seeks to explore and analyse how to fundamentally improve the efficiency and effectiveness of technology transfer from a broader perspective. As Bradley et al., (2013) summarises the traditional university technology transfer model, the current linear technology transfer model is no longer adequate for complex technology transfer activities.

Recognizing this inherent limitation, this thesis assumes paramount significance. Our aim is to delve deep into the realm of university technology transfer, drawing upon a rich tapestry of both scholarly literature and real-world experiences.

In essence, this thesis strives to transcend the confines of the conventional model by offering a nuanced and comprehensive understanding of university technology transfer. By synthesizing insights garnered from academic research and practical endeavours, we endeavour to shed light on the multifaceted nature of this process. Our aspiration is not merely to critique the existing

model but to provide a robust reference point—a guide that empowers universities and stakeholders to redefine and optimize their technology transfer endeavours.

To expand the theoretical framework of this dissertation, recent literature on the quadruple and quintuple helix innovation systems has been integrated. As noted by Carayannis and Campbell (2020), these models extend traditional innovation theories by incorporating the roles of government, civil society, and the environment, thereby offering a comprehensive perspective on sustainable innovation ecosystems. This addition deepens the analysis by contextualizing the dynamic interplay between diverse stakeholders in higher education. Additionally, insights from Wessel et al. (2021) on digital transformation emphasize how technological integration transforms technology transfer processes, enabling HEIs to adapt more effectively to changing innovation landscapes.

Through this comprehensive exploration, we aim to equip institutions with the knowledge and insights required to transcend the limitations of a linear paradigm. Our goal is to foster adaptability and resilience within university technology transfer, enabling institutions to not only thrive in the face of evolving challenges but also to catalyse innovation and societal progress in ever more meaningful ways. In doing so, we envision a future where the technology transfer landscape is marked not by rigidity, but by its capacity for dynamic transformation and sustainable impact.

The role of technology transfer within Higher Education Institutions (HEIs) has garnered significant attention in academic circles. This emphasis stems from technology transfer's potential to convert academic research into tangible market applications, driving innovation, regional development, and economic progress. Consequently, understanding the frameworks and models that guide this process within HEIs is of utmost importance, both from an academic and practical standpoint.

Existing literature provides a foundation by presenting models that capture the dynamics of research, development, and technology transfer within these institutions. However, the ever-evolving nature of technology and its integration with academia necessitates continuous evaluation and refinement of these models. The Tetris project emerges as a valuable empirical source, shedding light on contemporary practices and offering a real-world reflection of how HEIs engage with technology transfer.

Research Questions

Given this context, the research aims to address the following questions:

What are the predominant models in existing literature that detail the processes of technology transfer within HEIs? (In Research and development，ecosystem，and changing environment three dimensions)

What are the key resources, strategies, and support systems required by HEIs to optimize their technology transfer processes?

Based on the synthesis of literature and Tetris project insights, can a refined and relevant model be developed to guide technology transfer in modern HEIs?

By addressing these questions, this research seeks to provide a clearer understanding of the current state and future potential of technology transfer within the higher education sector.

Methodology

This research seeks to offer a detailed understanding of technology transfer management within higher education institutions (HEIs). To do this, the methodology we've adopted a triangulation approach, combining bibliometric analysis, survey data from the Tetris Project, and business process modelling. The bibliometric analysis established a comprehensive perspective on the scholarly discourse on technology transfer, while the survey data provided empirical insights into institutional practices. Process modelling then synthesized these findings to develop adaptive generalizability strategies that are appropriate for the context of higher education institutions. To address potential data collection issues, we developed contingency plans, including alternative data sources such as interviews and focus groups and enhanced interactions with participants. These measures were designed to ensure the integrity of the data and reduce the risk of bias or incomplete datasets.

Comprehensive Literature Review and Model Development

The primary phase of our methodology is grounded in an extensive literature review. Through a systematic exploration of existing scholarly works, we aim to identify and synthesize previous models that encompass the research and development process within HEIs, the broader ecosystem in which these institutions operate, and the specific nuances of technology transfer in an evolving environment.

The intention behind this literature-driven modelling is twofold. Firstly, it seeks to provide a comprehensive understanding of historical and contemporary paradigms of technology transfer management in higher education. This facilitates the contextualization of our subsequent analysis within established academic frameworks.

Survey from Tetris Project: Empirical Insights

Building on our theoretical framework, we utilize empirical data from the Tetris project. The Tetris project survey, targeting technology transfer offices (TTOs) of partner universities, is employed to capture a granular understanding of HEI operations in technology transfer.
Although our sample size covers only 14 institutions, these universities are representative of their local context. They are further categorized into three tiers based on their technology transfer capability: low, medium, and high. This tiered approach allows for a nuanced comparative analysis, identifying varied challenges and needs across the spectrum.
Key areas of the questionnaire and workshop discussion encompass publications, presentations, intellectual property management, contract research, institution-industry staff exchange, consultancy, licensing, and spin-offs/start-ups, among others. This provides a panoramic view of technology transfer channels and strategies.

Collaborative Group Dynamics in Technology Transfer Workshops

This study employed collaborative workshops as a core methodology to gather practical insights into technology transfer (TT) challenges and strategies in higher education institutions (HEIs). Within the TETRIS project, workshops held in Cartago and San Sebastian organized participants into thematic groups based on expertise, focusing on domains like Intellectual Property Management, Research Management, and Entrepreneurship.

Each group was led by a facilitator and a rapporteur, fostering structured discussions and ensuring that insights were systematically documented. This collaborative setup enabled participants to contribute diverse perspectives, allowing for a thorough exploration of TT issues. The data generated through these group dynamics provided a foundation for the TT model in this dissertation, emphasizing the importance of adaptability, interdisciplinary collaboration, and ecosystem engagement.

These workshops contributed real-world perspectives that strengthened the dissertation's empirical basis, allowing for a nuanced approach to developing adaptive TT frameworks in HEIs.

Business Process Modelling: Process-Oriented Analysis

Transitioning from empirical data to analytical design, the business process model is employed. The business process model is particularly apt for this study as it allows for a systematic

representation, analysis, and optimization of technology transfer processes. Its structured approach facilitates the visualization of operations, identification of bottlenecks, and the design of optimized workflows.

By integrating insights from the literature and Tetris questionnaire, this model offers a holistic perspective, aligning theoretical constructs with real-world challenges and solutions.

Synthesis and Refinement of Model Design

Finally, the research brings together theoretical, empirical, and process-oriented insights. By overlaying our literature-based model with empirical findings and the structured approach of the business process model, we create a refined, contextually relevant design.

This model is iteratively adapted to ensure it captures current challenges and maps out optimal strategies for technology transfer within HEIs.

In conclude, our comprehensive methodology, with its juxtaposition of literature, empirical data from the Tetris project, and the strategic lens of the business process model, seeks to chart a robust blueprint for technology transfer management in higher education. This fusion offers HEIs a balanced perspective, combining academic insights with pragmatic strategies, fostering enhanced technology transfer outcomes.

About Tetris Project

Data were collected through questionnaires and focus groups with TTO officials at partner universities and technical institutions through the TETRIS project. The data collected by the focus group of TTO officials mentioned here is divided into two steps. The first is to conduct group discussions to collect data. It is found that there are many obstacles to using the TT process. If the TT process is clearly defined and supported by an effective information system, many obstacles can be removed. As one of the contributors to the Tetris Project, my responsibilities include participating in data collection efforts across institutions, creating figures for technology transfer performance assessment guidelines, attending workshops, and engaging stakeholders in discussions on technology transfer practices. These activities provide important insights into the challenges and opportunities of implementing technology transfer models in different institutional contexts.

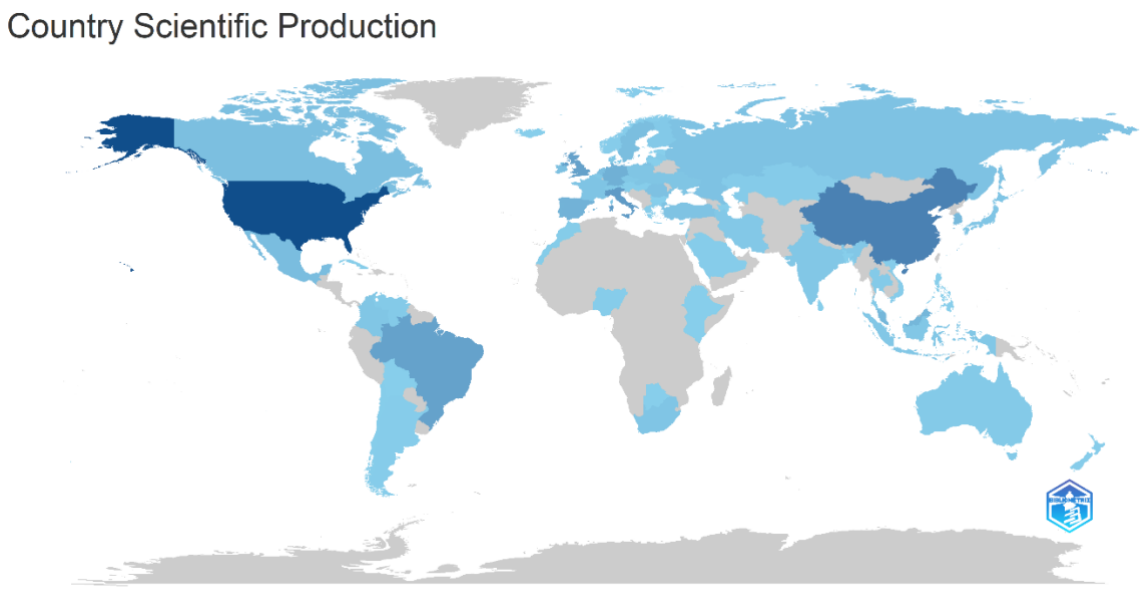
The selection of partner HEIs for the Tetris Project is based on diverse institutional profiles that capture varying technology transfer capacities. Institutions were chosen to represent different levels of research development, ecosystem engagement, and adaptability. By including HEIs with distinct demographic and geographic contexts, this study allows for a

comparative analysis that reflects real-world diversity. This selection strategy not only enhances the generalizability of the findings but also allows for nuanced insights into how contextual factors influence technology transfer mechanisms.

To identify barriers and facilitators in the university technology transfer process, a roundtable was held with technology transfer department officials from nine universities in Latin America and Europe (Portugal, France, Spain, Germany, Bolivia, Colombia, Costa Rica, Ecuador, and Panama). After collecting and analysing personal experiences and observations, three working groups were formed, with each member of each working group describing the barriers and enablers they faced in applying the TT process. Information is systematized and grouped according to the following processes: Intellectual Property Management; Research Management; Entrepreneurship Management; Service Management; Human Resources Management of the Technology Transfer Office; Financial Management; Management of Regulations and Laws.

To verify the information collected, systematic documents were exchanged between the groups. During this process, the leaders of each group introduced the situation, and other group members also put forward suggestions and opinions. Finally, the information was consolidated in a single document and presented to all participants at a plenary session.

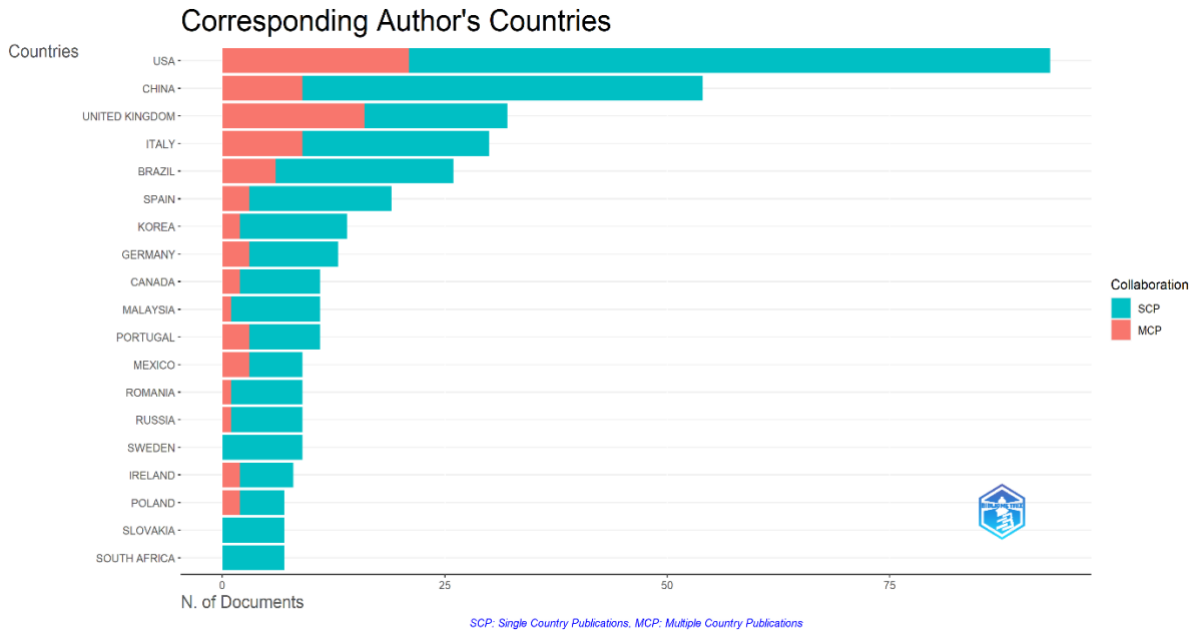
Universities seeking to implement an efficient technology transfer activity need a set of policies, tools, culture, and people for effective intellectual property (IP) management and knowledge transfer. The purpose of this survey is to collect information about the TTOs of the partner universities in TETRIS project.



5. Figure Country Scientific Production in the field of technology transfer within higher education institutions in recent years till 2023

Source: Made by the author, the darker the colour, the more intensive the output is.

Recent bibliometric analyses (5. Figure) have revealed significant trends in international collaboration in the field of technology transfer within higher education institutions. Statistical assessments based on country of publication indicate that authors in this field frequently collaborate across borders, highlighting significant moves towards internationalisation of research (6. Figure). This pattern not only reflects the inherently global nature of technology transfer but is also consistent with the current trajectory of academia towards greater interconnectedness. This internationalisation is indicative of the growth of the field, where knowledge sharing and collaborative efforts have become the hallmark of technology transfer research.



6. Figure Corresponding Author's Countries in the field of technology transfer within higher education institutions in recent years till 2023.

Note: SCP: Single Country Publication, MCP: Multiple Country Publication

Research and development (R&D) –model/type 1

As academic institutions evolve into innovation hubs, the importance of research and development (R&D) models in higher education has become increasingly prominent (Radović et al., 2023). Higher education institutions play an important role in driving the growing demand for groundbreaking research, technological innovation, and economic development. A case in point is the Massachusetts Institute of Technology (MIT), which is renowned for its innovative R&D approach in collaboration with industry and government, highlighting the significant impact of collaborative efforts in advancing real-world solutions (Khan et al., 2022). The nature of higher education institutions that combine knowledge creation with real-world applications highlights the dual task of universities in academic advancement and practical solutions (McDonnell-Naughton, 2022). The functions of creating new technologies, cultivating critical thinking, and stimulating economic growth through innovation and entrepreneurship make higher education institutions key players in addressing global challenges (Stolze et al., 2022).

The Oslo and Frascati Manuals, emanating from the OECD, offer pivotal guidelines for interpreting the nuanced domains of innovation and research and development (R&D) within the global context. The Frascati Manual, with its roots stretching back to 1963, stands as the

benchmark for methodically capturing R&D statistics, providing a clear taxonomy for research activities and expenditures. Its successive updates (OECD, 1980, 1993, 2005, 2015) mirror the shifting contours of the research landscape, with its latest edition accentuating the inclusion of the humanities and social sciences within R&D narratives (OECD, 2015). The Oslo Manual, since its inception in 1992, has complemented the Frascati Manual by shedding light on the broader spectrum of innovation. It has evolved from a focus on technological innovation to a more holistic view that encompasses organizational and marketing innovations, spotlighting the role of the public sector as an innovation catalyst (OECD, 2005, 2018).

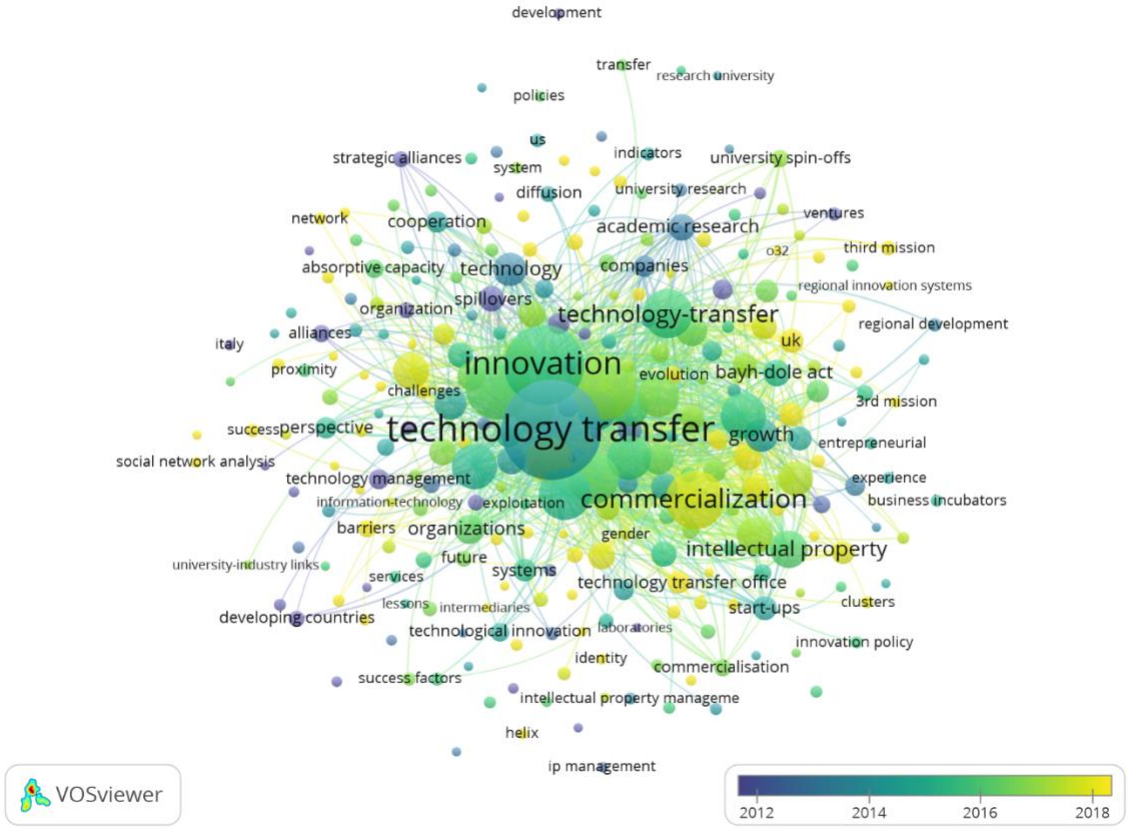
For higher education institutions, these manuals are more than just reference texts; they are instrumental in shaping their research and innovation strategies. The Frascati Manual empowers HEIs to align their R&D activities with international standards, enhancing their global standing and collaboration potential. It also aids in refining investment strategies by offering a recognized framework for R&D expenditure categorization.

Technology Transfer Offices within HEIs particularly benefit from the Oslo Manual's expansive view of innovation. Its guidelines enable TTOs to identify and navigate diverse pathways for the commercialization of research, acknowledging the importance of both technological and non-technological innovations in today's interconnected world.

Together, these manuals encapsulate the dynamic evolution of R&D and innovation, reflecting and adapting to the changing tides of global research imperatives. For HEIs, adherence to these guidelines ensures systematic, internationally coherent R&D efforts, and paves the way for contributions that have a tangible impact on society and the global economy.

The Frascati Manual's later edition (OECD, 2015) describes research as "creative and systematic work that increases the stock of knowledge". It involves collecting, organising, and analysing information to increase understanding of a subject or problem. Research and Development is defined as any systematic and creative work undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new applications. R&D activities include basic research, applied research, and experimental development.

Research and development management in higher education institutions is a complex process, and the existing literature indicates that universities need to effectively evaluate some aspects of research and development activities by calculating their return on investment (Aziz & Tran, 2022), performance evaluation (Jalaliyoon & Taherdoost, 2012), monitoring and evaluation through performance indicators (Tijssen, 2011).



7. Figure Bibliographic map (WOS) in technology transfer field till 2023 -keywords co-occurrence

The visualisation provided by VOSviewer provides a bibliometric analysis of key terms related to technology transfer within higher education institutions. Nodes (or circles) represent key terms, and their size indicates how often the term appears in the literature. Lines between nodes indicate the strength of association between terms, with thicker lines indicating stronger associations. The colour gradient from blue to yellow indicates the timeline of keyword occurrence and prevalence, with blue representing earlier occurrences and yellow representing more recent occurrences.

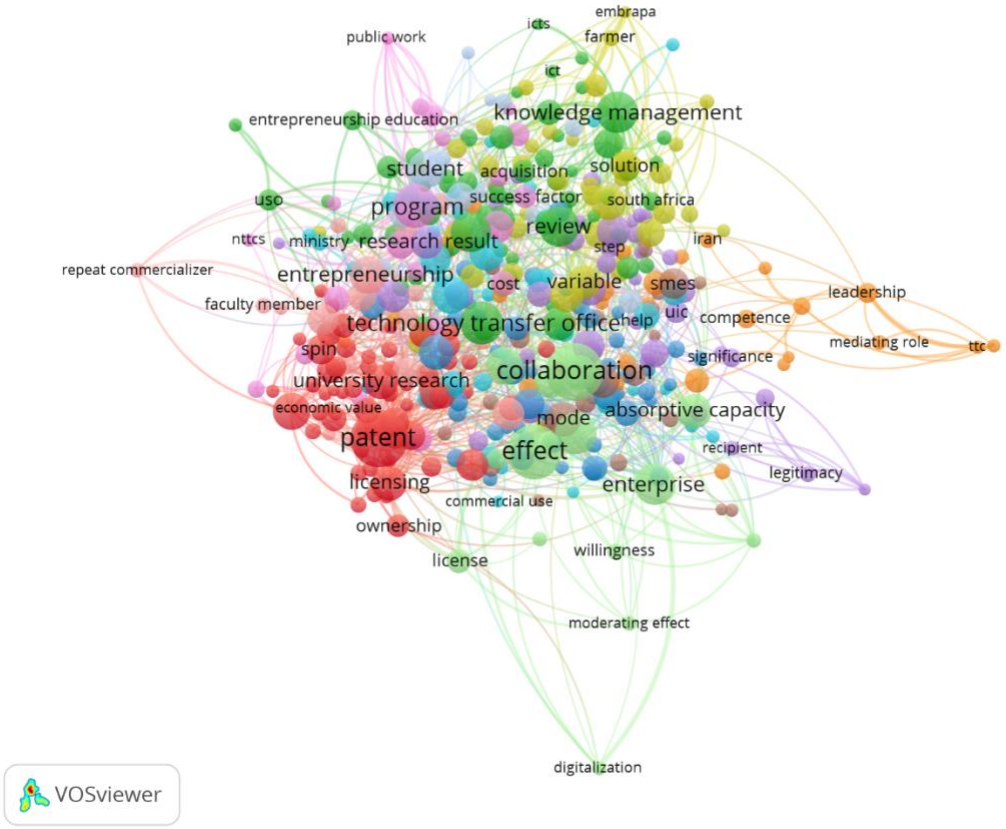
What we can see from 7. Figure is that the central and largest nodes for 'technology transfer', 'innovation', 'commercialisation' and 'intellectual property' indicate that these are foundational concepts for the field. The proximity of 'technology transfer', 'innovation', 'commercialisation' and 'intellectual property' to 'innovation' and 'commercialisation' reflects the core of the process in HEIs: the translation of academic research into marketable products or services. The terms 'technology transfer offices', 'start-ups' and 'intellectual property management' are gradually changing from blue to yellow, indicating their growing importance in recent discussions and the maturing infrastructure of HEIs to support these activities.

The emergence of nodes such as 'university-industry linkages', 'strategic alliances' and 'collaborations' emphasises the importance of academia-industry collaboration, which is essential for effective technology transfer. The linkages with 'regional development' and 'regional innovation systems' indicate an awareness of the socio-economic impacts of technology transfer. This suggests that HEIs are not only participants in the innovation process but also contributors to regional growth and development.

The emergence of terms such as "gender" and "developing countries" in recent years showed that research in the field had diversified, considering broader socio-economic factors and inclusiveness. The overall structure of the network, including interconnected nodes and clusters, depicts a complex and interconnected field. It demonstrates that technology transfer in HEIs is not linear, but rather a multifaceted process influenced by a variety of factors such as policy, collaboration, and socio-economic context.

Overall, this visualisation captures the multifaceted nature of technology transfer in HEIs, highlighting the centrality of innovation and commercialisation, the importance of strategic partnerships, and the growing complexity and international scope of the field. It also reflects the growing recognition of the need to understand the broader implications of technology transfer for society and the global economy.

The administrative system of universities is also worthy of attention. The support of the administrative system is crucial to ensure the consistency of goals and tasks and to coordinate the operation of the research and management office with other departments of the institution. For example, reduce the complexity of the administrative system through Information and Communication Technologies and make it efficient (Krishnaveni & Meenakumari, 2010), the implementation of R&D projects requires the cooperation and support of all parties to achieve a higher success rate (Pinto & Slevin, 1989). Technology can increase the efficiency of research and management activities, but it can also lead to increased complexity and potential problems. The existing academic literature mainly focuses on the importance and effectiveness of planning and evaluation (Łącka & Brzezicki, 2020; Qin & Du, 2018). However, improving the efficiency of research and development is not a simple matter, and it faces many challenges. This paper believes that it is necessary to further study the structure of research and development management in higher education institutions, such as the mission of universities, research strategies, innovation strategies, research management and intellectual property (IP) management. At the same time, to demonstrate the potential of structured management of research and development in higher education institutions to increase the efficiency and effectiveness of research and management activities.



8. Figure Text map (WOS) in research and development in technology transfer in HEIs till 2023.

Source: Made by Author

7. Figure presents a comprehensive overview of the technology transfer process, encapsulating the broad spectrum of activities and interactions involved. In contrast, 8. Figure delves into the nuances of technology transfer within the context of a research and development model, highlighting the intricacies and specific mechanisms at play. The distinctions between these figures can primarily be attributed to the targeted approach in keyword searching, which serves to isolate the specific facets of technology transfer relevant to research and development activities.

This visualisation from VOSviewer provides a bibliometric map of keywords related to technology transfer in HEIs, particularly within the R&D model. The layout of the map shows thematic clusters that reveal patterns of relationships between concepts.

At the centre of the map, the terms 'technology transfer', 'patent', 'spin' and 'licensing' indicate that HEIs are very much concerned with the legal and commercialisation mechanisms of R&D. The proximity of 'patenting' and 'licensing' to 'technology transfer' suggests that intellectual

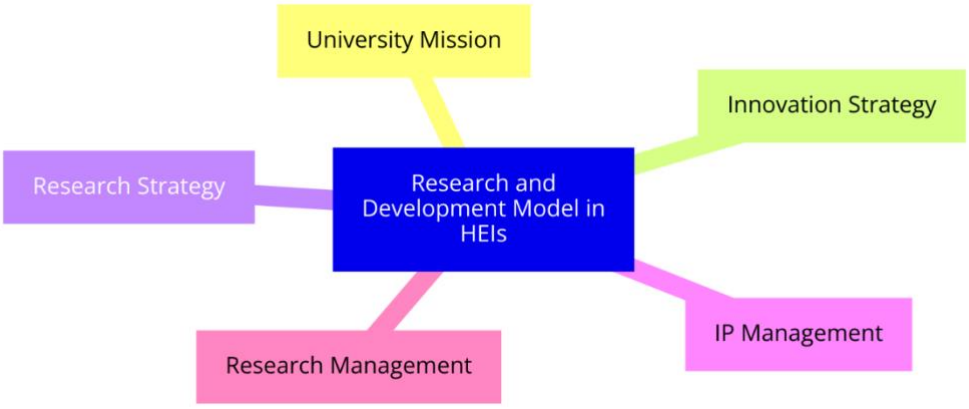
property plays a crucial role in the transfer of research results from HEIs to industry. Proximity clusters including 'entrepreneurship', 'spinouts' and 'university research' demonstrate the importance of entrepreneurial activities (e.g. spinouts) in creating economic value from academic research. This is consistent with the view that entrepreneurship within HEIs is an important part of the technology transfer process, as faculty and students commercialise their research.

The term "collaboration" is closely related to "enterprise", "effect" and "absorptive capacity", highlighting the importance of collaborative ventures between HEIs and enterprises. These partnerships are essential for effective technology transfer as they allow knowledge and resources to be shared for mutual benefit. The 'students' and 'entrepreneurship education' in the network emphasised the role of HEIs in developing the next generation of innovators and entrepreneurs. Such education is essential to equip students with the necessary skills to engage in and contribute to technology transfer activities.

The map also shows the geographical dimension of technology transfer research, with specific references to 'South Africa', among others, suggesting that research is focusing on technology transfer in different regional contexts, which may have unique characteristics and challenges.

In summary, this bibliometric analysis outlines the multifaceted nature of technology transfer in HEIs. It emphasises the interplay between R&D, IP management, entrepreneurship and collaboration. These elements are interwoven in a broader ecosystem that includes educational programmes, regional factors and entrepreneurial mindsets, all of which are critical to the viability and success of technology transfer programmes in R&D. It emphasises the interplay between R&D, IP management, entrepreneurship and collaboration.

In higher education institutions the research and development component is a cornerstone of the technology transfer process, where academic research is converted into tangible, often commercial, applications (Etzkowitz & Leydesdorff, 2000). This translation from theory to practice requires a comprehensive infrastructure (9. Figure).



9. Figure Research and Development Model in HEIs

- *University Mission:* An institution's R&D pursuits are intrinsically tied to its mission. Understanding a university's goals and objectives not only outlines the direction for academic endeavours but also sets the stage for tangible societal impact. This mission functions as a blueprint for all subsequent activities, ensuring alignment with the broader institutional ethos (Clark, 1998, Rana et al,2022).
- *Research Strategy:* Rooted in the university's mission, the research strategy provides a detailed road map for R&D efforts. It dictates the allocation of resources, choosing pertinent research topics, and fosters collaboration both internally and with external entities. By doing so, it ensures that the R&D aligns with the university's broader objectives and can lead to impactful results (Geuna & Muscio, 2009, Rasli et al,2022).
- *Innovation Strategy*: Beyond just research, HEIs need to consider how R&D outcomes translate to innovative solutions. This involves recognizing potential commercial or societal applications of research findings and facilitating mechanisms to bring these innovations to fruition (Solievich,2022).
- *Research Management:* Effective research management encompasses budget oversight, personnel management, and crucially, the act of technology transfer itself. With appropriate management, HEIs can ensure efficient utilization of resources and smooth transition from research to application (Namara,2023).
- *IP Management:* Intellectual Property is a crucial asset for HEIs, often stemming from R&D activities. Institutions must have robust policies in place to protect and manage this IP, ensuring they reap the benefits of their academic endeavours while also safeguarding the rights of the researchers involved (Siegel et al., 2003, Ravi & Janodia, 2022).

In essence, for HEIs, the journey from R&D to technology transfer and eventual societal impact is intricate. It requires a well-orchestrated strategy, rooted in the institution's mission, and encompassing all facets of research, innovation, and management.

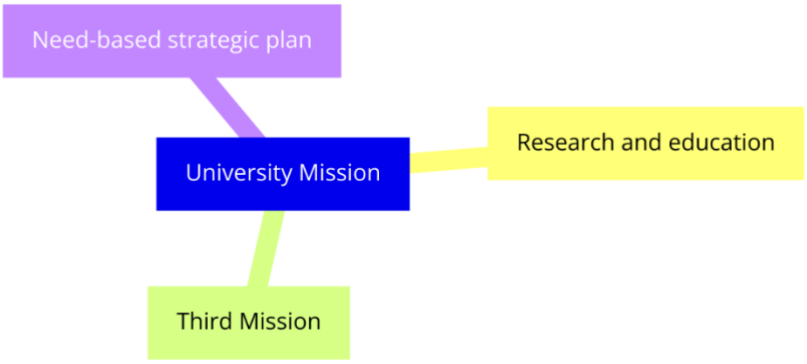
University Mission

The changing mission and values of the university by exploring the underlying mechanisms of the university's social influence (Carl & Menter, 2021). A sound university mission enables the development of a research strategy that focuses on the institutional mission and its overall goals. It also encourages universities to develop innovative strategies to help them remain competitive in a rapidly changing world.

Research and education have always been the two main tasks of higher education institutions. However, higher education has been given a third mission. This so-called 'third mission' is transforming the academic value of higher education institutions into the value of actively contributing to society (Zomer & Benneworth, 2011). The 'third mission' thus refers to the social, entrepreneurial and innovative activities that universities undertake in addition to their educational and research activities, with the aim of transferring knowledge and technology from academic institutions to society in order to solve real-world problems. While the process of commercialising technology transfer can be very income-generating, the resulting start-ups, spin-offs, incubators, etc. can further support technology transfer and thus enhance the reputation of higher education institutions. While the benefits of commercialisation can be a great incentive for both stakeholders and technology owners. Rather, the aim of pursuing a 'third mission' is to make a valuable contribution to society (Burd & Mars, 2013, Tien et al, 2022). Technology transfer centres help experts, inventors, staff and students in higher education institutions to develop ideas and create ideas for technology transfer. As a result, there is a growing consensus to increase the social value of technology transfer.
The definition of third mission is also guided by references to S3's Europe 2020 strategy, which aims to promote smart, sustainable and inclusive growth in Europe and its regions. Despite widespread recognition by universities, governments, industry and society that TM is becoming increasingly important, the concept of TM remains ambiguous. Indeed, it has been defined in a variety of ways, covering a wide range of models, dimensions, functions and activities, all of which have led to extensive debate among scholars and policy makers. There is no doubt that the growing body of research and interest in TM is reflected in the increasing

government pressure on universities to add a TM to their programme syllabuses, labelled 'contribution to society' (Compagnucci & Spigarelli, 2020).

The mission of universities has changed from maintaining the two major tasks of education and research to contributing to society. In this process, technology transfer or knowledge transfer has played an important role. Universities need to maintain continuous innovation and output in order to continuously contribute more technology and knowledge to society. Before universities plan how to better contribute to society, they need to have a needs-based strategic plan, which means making commitments in funding, human resources, research capabilities and partnerships (Tumwebaze Alicon, 2022), as shown in the 10. Figure.



10. Figure Research and Development Model - University Mission

Research strategy

Research strategy is the first step towards research management. It should identify signature research themes consistent with the institution's mission and the national and global higher education landscape. The strategy should i) outline the policy environment, ii) identify strengths, weaknesses, opportunities, and threats (SWOT), and iii) set priorities and objectives. While traditionally this may have been an informal process, today it is considered an essential part of good governance and management (Mittelmeier & Yang, 2022).

The Research Office is at the centre of an increasingly professionalized approach to research management, providing services to individuals and teams of researchers, and audit functions for both the institution and government agencies. The Technology Transfer Office is a relatively new addition and exists either as a sub- or separate unit. It is usually responsible for the commercialisation of intellectual property, patents, licensing and other forms of exploitation and company formation in addition to sector ‘intelligence’. This paper argues that

the technology transfer office should include the research office in order to better connect the research with external demands.

Changes in the external environment such as policy support the transformation of university research from a personal pursuit to an academic career requiring management. With research management and research offices playing an important role, it is all the more important how a university defines its research strategy, sets priorities and responds to emerging challenges (Hazelkorn & Herlitschka, 2010).

The reasons for developing research strategies naturally vary between universities, but also have commonalities, such as external pressures, increased competition and budget cuts, a desire for quality, there is a need for a more coherent approach and institutional support for dialogue with external partners. The increasing fragmentation of science also creates a need for opportunities for interdisciplinary research. Likewise, traditionally organized universities struggle to meet the "grand challenges" of modern society subject. Goals, choices, actions and communication are intermingled in the strategic plans of European universities field (Gunnarsson, 2012) as shown in the 11. Figure.

11. Figure Research and Development Model - Research Strategy

Innovation strategy

Schumpeter (1934) defined innovation as the process of introducing new combinations such as launching a new product or service, using new methods, opening a new market, or creating or destroying a monopoly organization. Innovation is both a process (Thompson, 1965) and an outcome (Barnett, 1953), encompassing new ideas, technology, or practices (Van De Ven, 1986).

An innovation strategy is an essential part of any organization looking to drive innovation and achieve long-term success. By outlining the goals and priorities of an organization's innovation activities, an innovation strategy helps focus efforts and resources to achieve those goals (Gulamov et al., 2022). One of the main benefits of an innovation strategy is that it promotes alignment within an organization. With a clear plan in place, different teams and departments can work together to achieve common goals rather than pursue their own individual priorities, this is about communication and collaboration in the organisation. This alignment helps maximize the impact of an organization's innovation efforts and can lead to better results. Another important benefit of an innovation strategy is that it prevents organizations from resting on their laurels. As new technologies and competitors continue to enter the market, organizations must stay ahead and innovate. By directing an organization's innovation efforts towards its goals, an innovation strategy can help ensure that an organization remains competitive, stays ahead, and continues to drive long-term growth and success (Mohamed Hashim et al, 2022).

The higher education innovation strategy could vary depending on the mission, goals, and needs of the university. However, in general, a university's innovation strategy could consist of the following elements:

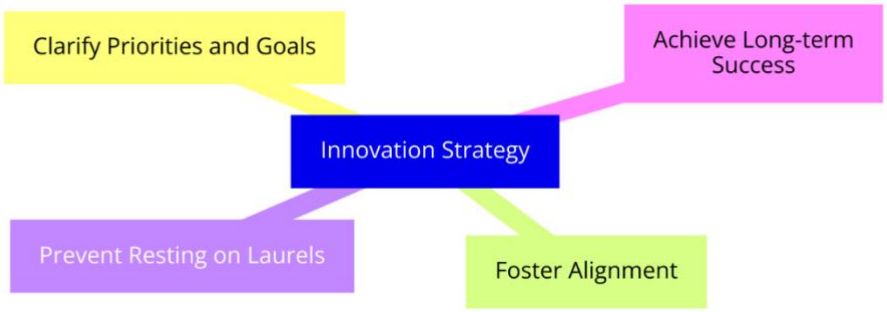
- Encouraging interdisciplinary collaboration between faculty, students, and researchers to drive innovation and promote creative thinking(Bromham et al., 2016).
- Developing new partnerships with businesses and organizations to bring research and innovation to market (Ankrah et al., 2015).
- Investing in research and development initiatives to drive innovation in key areas of focus for the university (Bozeman et al., 2013).
- Providing support for commercialization and entrepreneurship initiatives for students, faculty, and researchers (Hayter et al., 2017).
- Fostering a culture of innovation and creativity within the university community (Jackson, 2011).

The most concerned and core issues of a university's innovation strategy could vary, but some common concerns include:

- Ensuring that innovation activities align with the university's mission and goals (Cantwell & Kauppinen, 2014).
- Attracting and retaining top talent to drive innovation within the university (Franzoni et al., 2012).

- Securing funding and resources for innovation initiatives (Geuna & Muscio, 2009).
- Fostering collaboration and partnerships between academia, business, and government to maximize the impact of innovation activities(Perkmann et al., 2013).
- Developing a framework for commercializing and transferring innovations to market (Siegel & Wright, 2015).

These elements and concerns are meant to provide a general overview and could vary greatly depending on the specific needs and goals of the university as shown in the 12. Figure.



12. Figure Research and Development Model - Innovation Strategy

Research Management

Research management involves the effective coordination and optimization of research activities and outcomes by research-centred organizations (Mico University, 2019). It operates in a 'third space between professional and academic fields' and seeks to maximize research impact by combining research from multiple constituencies. To achieve this goal, research management includes various support activities that are critical at different stages of research, including identifying funding opportunities, supporting proposal preparation, implementing research projects, and assessing research impact (OECD, 2005). Effective communication and the use of appropriate tools and processes are crucial for the success of research management activities. It is important to note that research management is not the sole responsibility of a single institution or head of the research system but is carried out by agents at different levels of the research system. Effective research management requires collaboration and communication between these different levels, including researchers, funding organizations, research institutions, and government agencies (Mico University, 2019). The hierarchical structure of research management must be clear to ensure that all stakeholders are involved and working together towards maximizing research impact.

In order to produce high-quality, impactful research, institutions often emphasize research capacity monitoring. This involves assessing the capabilities, expertise, and infrastructure

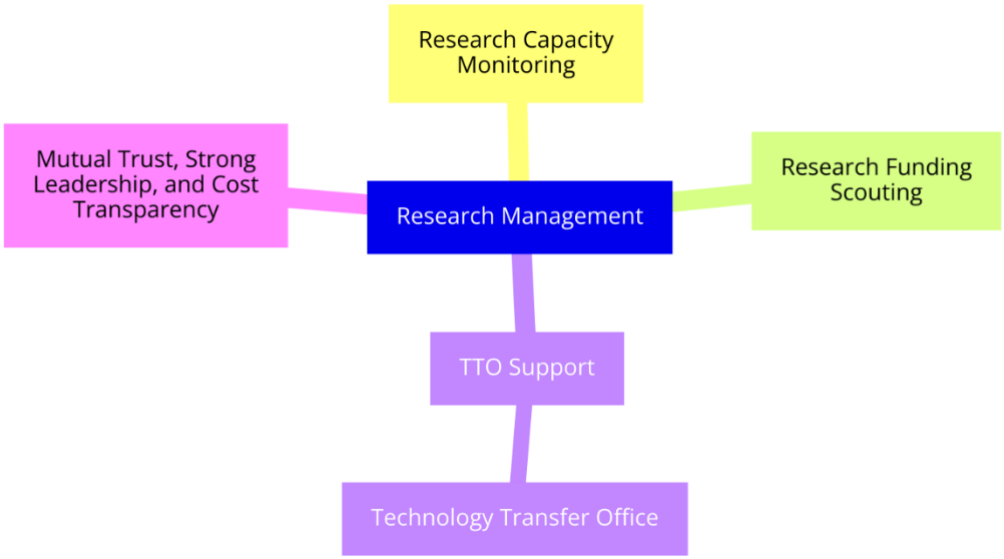
available within an institution, ensuring that there is a match between available resources and research ambitions. Such monitoring often aids in identifying areas of strength, as well as pinpointing where further investment or development might be needed (Hicks, 2012).

Simultaneously, an active approach to research funding scouting is essential. Given the competitive nature of research grants and the critical role funding plays in research progression, institutions often engage in proactive searches for funding opportunities. This involves understanding evolving research trends, aligning institutional strengths with funding priorities, and maintaining an awareness of both traditional and emerging funding sources (Geuna & Nesta, 2006).

An effective research management strategy also encompasses TTO support. TTOs play a pivotal role in bridging the gap between academic research and practical application, ensuring that innovations birthed in research labs find pathways to societal impact. They provide the necessary expertise in areas like intellectual property protection, commercialization strategies, and industry partnerships, thus facilitating the translation of research into tangible outputs (Siegel et al., 2004).

Lastly, but by no means least, underpinning effective research management is the importance of mutual trust, strong leadership, and cost transparency. Trust fosters collaborative research environments, ensuring that all stakeholders work synergistically toward common goals. Strong leadership provides direction, motivation, and clarity, steering research activities toward impactful outcomes. Meanwhile, transparency, especially regarding costs, ensures accountability, and efficient resource allocation, which are paramount in the often resource-constrained research landscape.

In conclusion, the research management landscape (13. Figure) is multifaceted, and effective oversight necessitates a balance of capacity monitoring, proactive funding strategies, effective technology transfer mechanisms, and a foundation of trust, leadership, and transparency.



13. Figure Research and Development Model - Research Management

Research funding

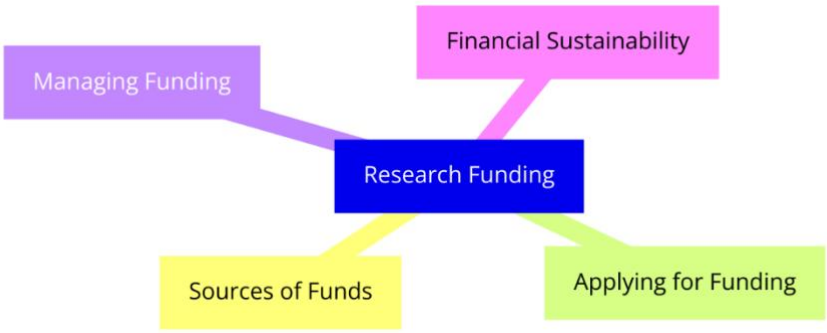
Research funding is critical to the success of the university and its ability to contribute to society through cutting-edge research and innovation. The regulatory framework within which a university operates plays a crucial role in determining its ability to access research funding and implement efficiency measures. For example, regulations that promote open access to data and information, and streamline the process of applying for funding, can help universities allocate resources and pursue innovative projects more efficiently. When colleges and universities receive external financial support, they often respond to external pressure and incentive mechanisms at the institutional level by adjusting institutional behaviour, and actively seek to improve efficiency at the institutional level. Achieving efficiency is indeed an important topic in most higher education systems. Collaboration between universities may help reduce costs. Internally, universities are increasingly focusing on process improvements, teaching practices, and workforce changes to improve efficiency and deliver "better value for money".

The degree of decentralization within a university also affects its ability to create efficiencies and secure research funding. Universities with more autonomy and decision-making power can better respond to the changing needs and opportunities of their communities and allocate resources more effectively. On the other hand, more centralized universities may have difficulty adapting to a changing environment and responding to new research needs and opportunities.

Collaboration between departments within a university can also play a key role in securing research funding and increasing efficiency. This may be driven by external pressure or incentives, such as government funding schemes that require cooperation or competition between universities. To be successful, collaboration must be based on mutual trust and strong leadership commitment as well as transparency and open communication about costs and benefits.

Finally, success in securing research funding and increasing efficiency requires a focus on cost transparency and clear, evidence-based decision-making. This could include measures such as performance-based funding, which rewards universities for specific research outcomes, or more efficient ways of tracking and reporting research spending. By focusing on these critical success factors, universities can more effectively allocate resources, pursue cutting-edge research, and drive innovation and progress.

Recent years, a plethora of literature underscored the intricate process of obtaining and managing research funds (14. Figure).



14. Figure Research and Development Model - Research Funding

- *Sources of Funds*: Various studies have elaborated on the myriad sources available for research funding. These range from governmental agencies, non-governmental organizations, private industry collaborations, to philanthropic entities (Hottenrott & Lawson, 2017). During this period, emphasis was also laid on the growing role of international collaborative funding where cross-border entities jointly fund projects of mutual interest (Wagner et al., 2019).
- *Applying for Funding*: The application process for research funding is competitive and multifaceted. The importance of aligning research proposals with the funding body's objectives, demonstrating the societal or commercial impact and ensuring rigorous methodology. Moreover, the increasing interdisciplinary nature of research required proposals to be comprehensible to a broader audience (Bozeman & Boardman, 2014).

- *Managing Funding*: Once obtained, the effective management of funds is paramount. The need for transparent financial management, periodic reporting, and ensuring that funds are utilized strictly for the purpose they were granted. This period also saw a rise in discussions about overhead costs, with many institutions looking for ways to streamline operations and reduce administrative overhead related to research funding (Hicks, 2012).
- *Financial Sustainability*: Beyond just securing initial funding, there's a growing need for financial sustainability in research. Laudel & Gläser (2014) discussed the challenges faced by researchers in maintaining a continuous stream of funding, emphasizing the importance of diversifying funding sources, reinvesting research-generated income, and building strong networks to ensure longer-term financial viability.

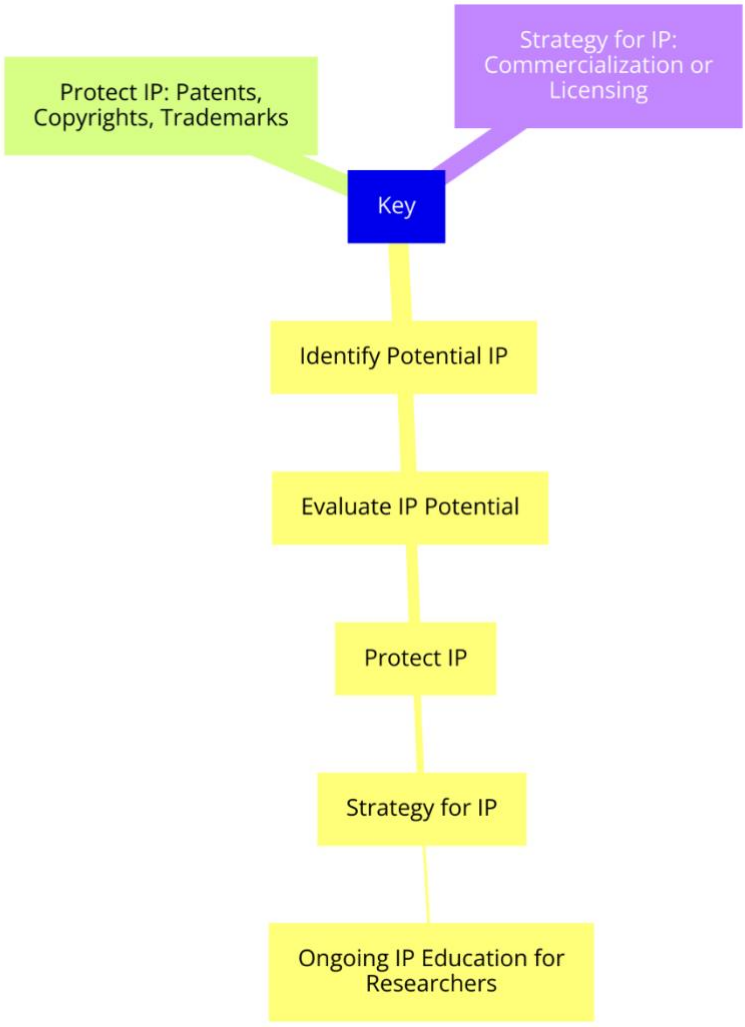
IP management

Intellectual property (IP) management strategies in HEIs can broadly be classified into proprietary and open-source models. Proprietary models, as seen in traditional patenting practices, offer comprehensive control over commercialization but may limit collaboration opportunities. In contrast, open innovation models, like the University of California's open-access IP policy, emphasize transparency and widespread dissemination of research outcomes. This policy has been instrumental in fostering collaborative research, resulting in a higher volume of industry partnerships. Through a critical analysis of these models, this chapter evaluates the conditions under which each approach optimizes technology transfer outcomes.
Intellectual property management is an important aspect of the innovation process as it helps to protect and monetize the results of R&D activities. Intellectual Property Policy provides researchers, innovators and institutions with guidance and regulations on how to handle and protect their intellectual property assets. According to Teixeira & Ferreira (2019), institutions with advanced knowledge and economic prosperity tend to have well-established IP management systems. The quantity and quality of intellectual property rights are important indicators to measure an organization's innovation performance and competitiveness. In the era of globalization, intellectual property rights have become an important part of strategic resource management and have a significant impact on the entire society (Grimaldi et al, 2021). Intellectual property management has important role in empowering research, development, and innovation. Intellectual property management covers policies, activities, tasks, and tools that manage the results of research-related activities and results. The following elements have

been identified as part of intellectual property (hereinafter referred to as the IP) management: IP policies, IP scouting, IP protection, IP valorisation, training and supporting tools. Institutions with advanced knowledge and economic prosperity usually have a good IP Management System. The quantity and quality of intellectual property rights is a significant indicator to weigh an organization's innovative performance and competitive strength (Teixeira, A.A. Ferreira, 2019). In the period of economic globalization, intellectual property has increasingly become the core element of using strategic resources and having a strong influence and impact on society at large.

All higher education institutions are concerned with the creation and dissemination of knowledge. The challenge for university IP managers, policy makers, and heads of academic departments is to discern the value of such knowledge and develop policies that best realize its value or asset. Once an institution has determined its overall business model, it needs to structure an IP policy to complement that model while delivering maximum benefit and implementing it appropriately across its disciplinary portfolio.

Intellectual Property management in higher education institutions is a nuanced process that ensures the protection and optimal utilization of research outputs. The literature emphasized a series of interconnected stages that HEIs undertake for effective IP management. First, the institution identifies potential IP from research outputs. Once identified, the IP undergoes a thorough evaluation for its commercial or societal potential. If deemed viable, the institution then proceeds to protect the IP, typically through patents, copyrights, or trademarks. With protection in place, the HEI can then strategize on commercialization or licensing opportunities, often in partnership with industry or through technology transfer offices. Throughout this process, ongoing IP education for researchers and students is crucial to ensure the sustained creation and protection of valuable IP (Siegel & Wright, 2015; Perkmann & Walsh, 2007, Mohamed Hashim et al, 2022). See 15. Figure.



15. Figure Research and Development Model - IP Management

Policies

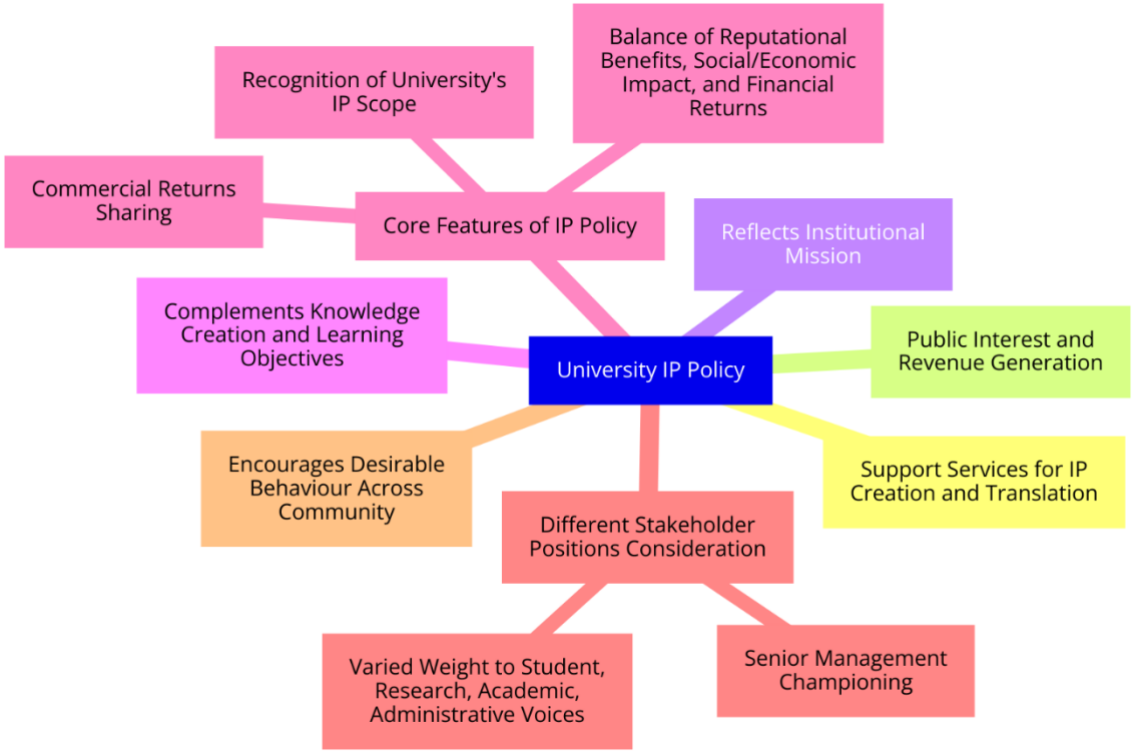
Technology-driven innovation dominates all areas of society, especially human life, and creates a business economy based on "knowledge generation". Intellectual property is the intangible asset of any organization, which is more valuable than any tangible asset. And intellectual property policies are high-level principles, guidelines, and rules regarding to the above-mentioned fields. Trommetter (2008) mentioned that universities should be aware of the identification, protection, management, use and benefit of intellectual property rights and formulate corresponding policies to guide operational behaviour. The core purpose of the intellectual property policy is to provide a framework to declare and protect the rights of universities and university staff (Rooksby, 2020). Another goal to provide guidelines for industry, government, and other communities to make use of universities' intellectual property for national and global interests (Holgersson & Santen, 2018). Thereby promoting the transfer of technology produced by universities, foster university innovation and creativity, local and

national economic growth. Based on the continuous development of technological explosions, "knowledge assets", various institutions and stakeholders have become the triggers of IP policy formulation (Busch, 2023).

A university intellectual property policy should reflect the mission of the institution. IP policies must complement the core objectives of knowledge creation, scholarship and learning. It is the institution's responsibility to develop policies and support services that create the best possible environment for the creation and translation of IP into practical use, but in a manner that is in the public interest and generates revenue for the originating institution and students/researchers. The core features of an IP policy should be:

- Arrangements to share any commercial returns from the commercialization of IP, providing appropriate benefits to the originator of the IP.
- Recognition of the scope of the University's IP activities; and
- Balancing reputational benefits, positive social and economic impact, and financial returns from doing IP work.

Those drafting IP policies should reflect the positions of different stakeholders in academia. While it is important for senior management to champion a policy to give it the respect it deserves, different institutions may give different weight to the voices of the student, research, academic or administrative communities in their policies, again suggesting a 'one size fits all' method does not apply. When developing a set of policies, the agency needs to ensure that it encourages desirable behaviour in every part of its community.



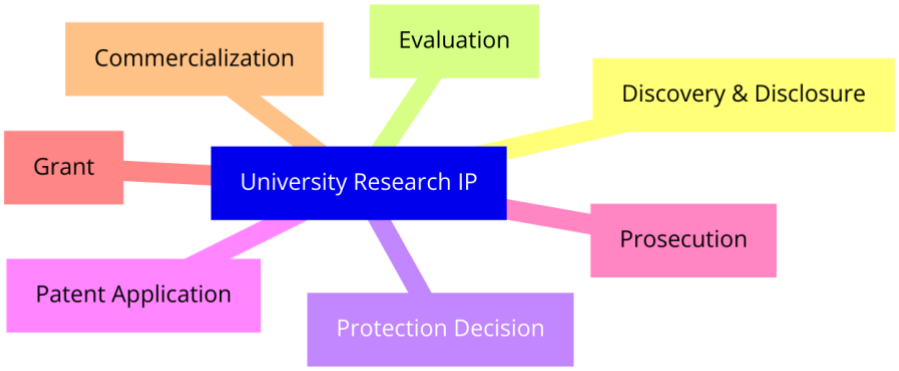
16. Figure Research and Development Model - IP policies

Patenting

Many university research results are still a long way from the market. This is often the case with university-patented technologies. Universities must assess how close any IP is to the market and develop an appropriate strategy. For example, cold selling a research opportunity to a business can be challenging. However, the benefit of patented technologies is that they effectively express research results in the form of products that can be commercialized; alternatively, they can enable universities to express complex scientific activities in a language that companies can understand. This then creates an avenue to open a dialogue with the company, which could lead to companies investing in research relationships through licensing deals as part of the overall deal. However, universities should view their IP strategy as part of their research strategy rather than a revenue strategy.

The patenting process for university research results generally involves a sequence of actions, starting from the discovery of potentially patentable research results to the eventual protection of the intellectual property. Drawing from literatures, the process can be summarized as follows (17. Figure):

- *Discovery & Disclosure:* Researchers realize they have potentially patentable results and disclose these to the university's technology transfer office (TTO) or equivalent body (Conti et al, 2013).
- *Evaluation:* The TTO assesses the patentability of the discovery and its potential commercial value.
- *Protection Decision*: If the invention is deemed patentable and has potential value, a decision to proceed with the patenting process is made (Siegel & Wright, 2015).
- *Patent Application*: The TTO, often with the help of external patent attorneys, drafts and submits a patent application to the patent office (Grimaldi et al., 2015).
- *Prosecution*: This involves correspondence with the patent office to clarify, adjust, or defend the patent claims (Singh & Hooda, 2023).
- *Grant:* If successful, the patent application results in a granted patent, giving the university rights to the invention for a set period, usually 20 years.
- *Commercialization:* The university, often through the TTO, seeks to commercialize the patent, either through licensing agreements, creating spin-off companies, or other avenues (Perkmann et al., 2013).



17. Figure Research and Development Model -Patenting

Protection

Intellectual property, an amalgamation of patents, copyrights, and trademarks, provides creators and inventors with legal avenues to earn recognition or monetary gains. This legal framework balances the innovator's interests against the larger public good, creating a conducive environment for creativity and innovation to thrive. Given the intangible nature of these assets, it's imperative they receive protection akin to tangible assets (Lemley, M.A., 2015).

Universities, as crucibles of innovation, recognize the value of IP protection. While academic freedom to publish remains paramount, there's an understanding that prior protection of intellectual property related to research is essential before any publication, especially if there's potential commercial utility (Conti, 2013).

The process of IP protection is multifaceted and can be delineated into the following primary and secondary processes (18. Figure):

1. IP Due Diligence

- Evaluate potential IP rights from research: Before diving into the patenting or other IP protection processes, it is essential to evaluate the novelty and utility of the discovery. This step ensures that efforts are placed on IPs with potential commercial or societal impact.
- Perform clearance searches: Such searches are crucial to ensure that the IP in question does not infringe upon existing intellectual properties. It is a preventative measure to mitigate potential litigation risks.
- Determine feasibility of IP registration: Not all IPs are suitable for registration. Determining its feasibility ensures that resources are channeled effectively.

2. IP Ownership

- Define and document IP ownership: Clear documentation regarding IP ownership is crucial, especially in university settings where multiple stakeholders, such as professors, students, or external collaborators, might be involved.
- Determine rights & responsibilities: This step involves clearly delineating the rights of each stakeholder involved in the IP's creation, ensuring clarity and preventing potential conflicts.

3. Confidential Information

- Protecting the confidentiality of sensitive information related to the IP, especially in the early stages, can be instrumental in retaining its commercial value and preventing unintentional disclosures.

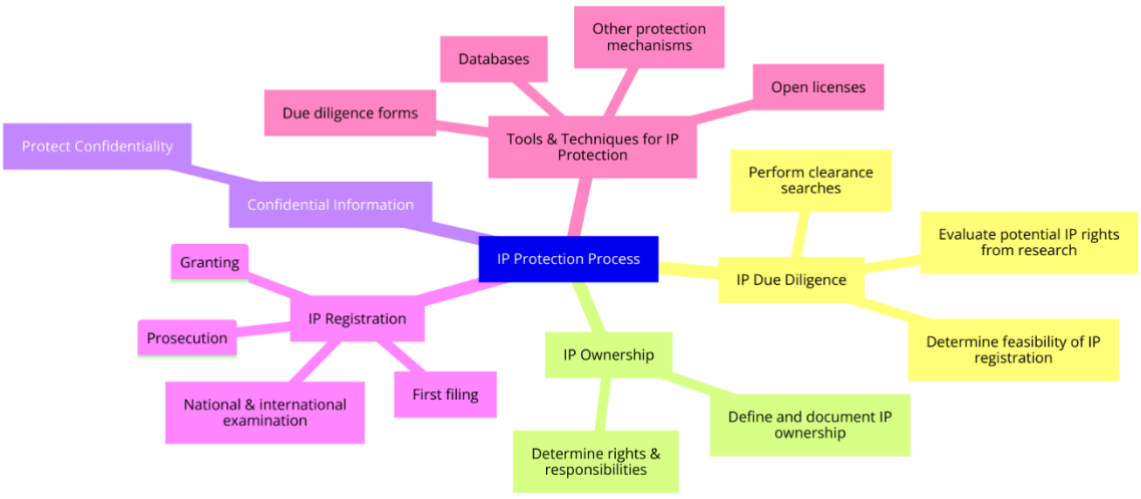
4. IP Registration

- First filing: Often, a provisional patent or a similar filing is made to secure an early priority date, which can be crucial in the competitive world of IP.
- Prosecution: This involves the back-and-forth communication with the patent office to address any issues or concerns they might have about the IP.
- National & international examination: If the IP has global relevance, it will undergo scrutiny in multiple jurisdictions, each with its unique set of rules and processes.
- Granting: If all the examinations are successful, the IP is granted, providing the owner with a set of exclusive rights, typically for a defined period.

5. Tools & Techniques for IP Protection

Modern IP protection in universities requires a suite of tools and techniques to effectively manage and safeguard IPs (Wagner & Wakeman, 2016):

- Due diligence forms: These standardized forms help streamline the due diligence process, ensuring that no step is overlooked.
- Databases: Intellectual Property databases assist in clearance searches, tracking IP statuses, and maintaining a repository of all IPs owned by the university.
- Open licenses: In some cases, universities opt to use open licenses, allowing wider dissemination while still retaining some control over the IP.
- Other protection mechanisms: Depending on the nature of the IP, other mechanisms such as trade secrets, copyrights, or trademarks might be employed.

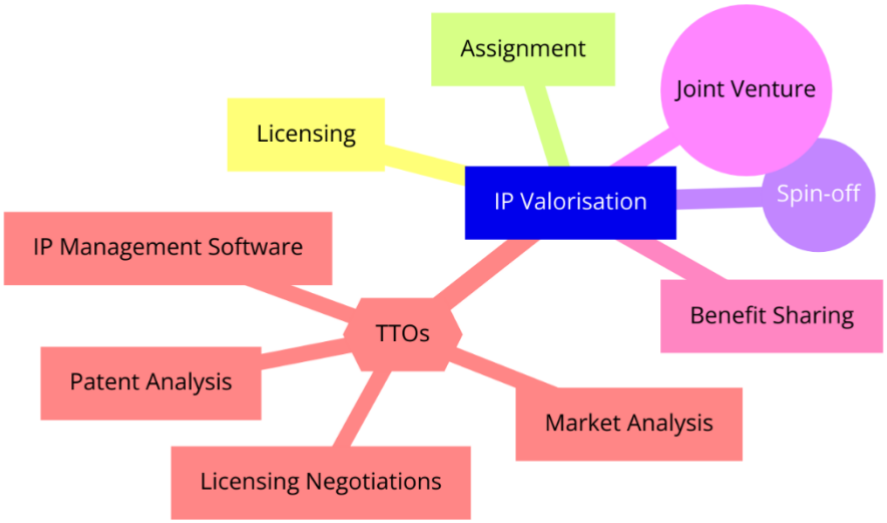


18. Figure Research and Development Model - IP Protection

Valorization

IP Valorisation refers to the process of converting the results of research and development into commercial or societal value. The goal of IP Valorisation is to ensure that the results of the research are not just published in academic journals, but also put to practical use for the benefit of society（Siegel, et al.2003). There are several different ways to valorise IP, including licensing, assignment, spin-off, joint venture, etc. Licensing involves allowing a third party to use the IP in exchange for a fee. Assignment involves transferring ownership of the IP to another party. Spin-off involves creating a new company based on the IP. Joint venture involves partnering with another organization to develop and commercialize the IP. The regulations on ownership and incentives of IP vary by country. In some countries, universities own the IP generated by their researchers, while in others, the researchers themselves own the IP. Incentives for IP valorisation also vary, with some countries offering tax breaks or other financial incentives for companies that invest in research and development (Geuna & Nesta, 2006). Benefit sharing refers to the distribution of the benefits generated by IP. There are several different models for benefit sharing, including profit sharing, royalty-based models, and equity-based models. The principles of benefit sharing include fairness, transparency, and inclusiveness.

IP valuation can occur in both publicly and privately funded research. In publicly funded research, intellectual property is often owned by the funding agency, which then seeks to commercialize it. In privately funded research, the intellectual property is owned by the company funding the research. TTOs can support the definition and deployment of IP development strategies by providing researchers with expert guidance and support to commercialize them in the most appropriate way. TTO also connects industry partners, licensing partners and investors, helping researchers connect with the resources they need to commercialize their intellectual property. Finally, TTOs can assist in drafting and negotiating agreements related to the protection and exploitation of intellectual property, such as non-disclosure agreements, material and related data transfer agreements, and licensing agreements. Researchers, TTOs, industry partners, licensing partners, investors and legal advisors are all involved in the IP Valorisation process. Tools and techniques used in IP Valorisation include market analysis, patent analysis, licensing negotiations, and intellectual property management software. These tools and techniques are used to determine the best way to commercialize intellectual property and ensure it is protected and well managed.



19. Figure Research and Development Model -IP Valorisation

The literature on the Research and Development (R&D) model or Type 1 model in technology transfer (TT) emphasizes several foundational elements necessary for HEIs to effectively translate research into market-ready solutions. Central themes in this body of research include the importance of robust research funding, IP management, innovation strategy, research management, and a supportive entrepreneurial ecosystem. Studies highlight that a stable funding base is crucial for sustaining research efforts, enabling institutions to conduct high-impact research with commercial potential (Geuna & Muscio, 2009). Furthermore, research underscores that structured IP management policies are essential for protecting research outputs and maximizing their commercialization potential (Markman et al., 2008). Effective research and innovation strategies are also emphasized, with scholars like Siegel et al. (2003) advocating for strategic alignment of research initiatives with market demands to optimize TT success. Additionally, Wright et al. (2007) emphasize the role of entrepreneurial ecosystems, noting that support for spin-offs, startups, and industry partnerships fosters a pathway from academic research to commercial application.

However, the literature indicates that successful implementation of the R&D model requires comprehensive data on these foundational elements to allow HEIs to make informed improvements. Data gaps exist, particularly around how HEIs manage the alignment of research strategy, monitor research capacity, and engage with industry, government, and civil society in a way that supports adaptive and sustainable TT practices. To address these gaps and assess the alignment of institutional practices with the R&D model, the study utilizes a

questionnaire survey and focus group discussions, each tailored to capture essential data in support of this model.

Based on the literature, the survey questionnaire includes the following key questions aligned with the core elements of the R&D model:

- Research Funding: Questions on the sources and diversity of research funding (e.g., regional, national, international grants) and the institution's R&D income aim to capture the financial support systems in place, as well as how effectively institutions leverage diversified funding for TT.
- Research Capacity Monitoring: Questions about tracking the availability and expertise of researchers provide insights into how institutions manage research capacity, ensuring alignment between resources and impactful research areas.
- IP Management: The survey addresses IP policies, ownership rights, IP protection practices, and IP training for staff and students, as these elements are vital to maintaining a strong IP framework that supports commercialization and protects institutional rights.
- Innovation Strategy and Entrepreneurial Support: Questions about support for entrepreneurship, startup foundations, and spin-offs capture how institutions foster innovation and build pathways from research to market. This entrepreneurial focus aligns with the model's aim to bridge academic research with commercial applications.

For additional elements mentioned in the R&D model that are not fully covered in the questionnaire, such as strategic partnerships, innovation management, and organizational structures, these topics are explored through focus group discussions. This approach enables a more in-depth examination of how institutions manage complex aspects of TT, including collaboration with industry and government, integration of market feedback, and organizational challenges in supporting innovation. Focus groups allow for rich, qualitative data collection on these nuanced areas, filling in gaps that the quantitative survey may not fully address.

In summary, the literature review highlights the critical components of the R&D model and establishes a rationale for gathering comprehensive data on funding, IP management, research capacity, and entrepreneurial support. To obtain a full picture of TT practices, the questionnaire survey captures structured data on key model components, while focus group discussions delve

into the remaining elements, providing a well-rounded assessment. This dual approach, grounded in the literature, ensures that the data collected will adequately support a thorough evaluation of the R&D model's implementation across diverse HEIs.

Ecosystem –model/type 2

Technology transfer is driven by ecosystems. As productivity and technology transfer from innovation continues to develop, the link between universities, organisations, individuals and industry becomes ever closer. This is reflected in the increasingly visible commercialisation of technology and the development of technology transfer ecosystems at all levels of the organisation. For example, incubators, technology transfer offices (Good et al., 2020). The uncertain and high- cost nature of innovation activities and the increasing combination of interdisciplinary fields and technologies have led to the emergence of open innovation models of collaborative innovation at all levels.

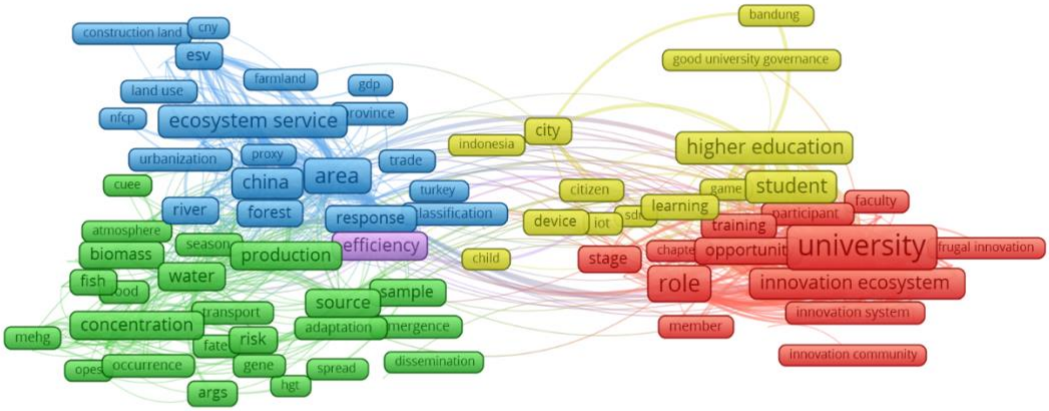
An ecosystem in the field of technology transfer in higher education refers to a dynamic and interconnected network of various stakeholders, such as universities, research institutions, industry partners, government agencies, and investors, working together to promote the commercialization of academic research and innovations (Etzkowitz & Leydesdorff, 2000).

Several researchers have contributed to understanding the technology transfer ecosystem in higher education. Etzkowitz et al. (2006) introduced the "Triple Helix" model, emphasizing the interplay between academia, industry, and government in fostering innovation. Siegel et al. (2003) examined university technology transfer offices (TTOs) and their role in facilitating research commercialization, while Rasmussen and Wright (2015) highlighted the importance of academic spin-off companies in driving economic growth.

Recent research has focused on various aspects of the technology transfer ecosystem. For instance, Rasmussen and Borch (2010) explored the role of academic entrepreneurs in the commercialization of university research, while Guerrero et al. (2021) investigated the impact of institutional factors, such as university policies and support structures, on technology transfer activities. Additionally, studies by Goel et al. (2018) and Huyghe et al. (2016) have analyzed the role of collaborative research and partnerships between universities and industry in enhancing the technology transfer process.

The author collected the web-based scientific literature (titles, abstracts, keywords) related to higher education institutional ecosystems over the last 30 years and developed the following 20. Figure for understanding the research trends and recent advances in higher education

institutional ecosystems, from which it can be seen that the clustering of the relevant terms may denote the different sub-themes or areas of focus in the area of technology transfer in the ecosystems." 'Higher education', 'university' and 'innovation ecosystem' are central nodes, suggesting that they are key concepts in the dataset analysed. Their centrality suggests that they are likely to be mentioned frequently and are closely related to many other terms. Terms close to these central nodes include 'student', 'teacher', 'role', 'opportunity' and 'learning'. This suggests that the focus of technology transfer is on educational and participatory aspects, with teachers and students playing a key role in creating opportunities for innovation. The link between 'universities' and 'innovation ecosystems' implies that universities are seen as part of a wider ecosystem that supports and promotes innovation. 'Ecosystem' in this context may refer to a complex network of stakeholders, including academia, industry, government and other stakeholders, who interact with each other to facilitate the development and transfer of technology. The close association of terms such as "training", "learning" and "stages" with "higher education" suggests that the effectiveness of the educational process itself in preparing individuals to engage in technology transfer activities is under scrutiny. The term "good university management" on the periphery of the network suggests that there is an ongoing discussion and data on how university management and policies can support or hinder technology transfer processes.



20. Figure WOS-based scientific literature related to higher education institutional ecosystems over the last 30 years

Source: Made by author

The technology transfer ecosystem in higher education institutions (HEIs) is a multifaceted structure involving the integration of various models and approaches aimed at fostering innovation and knowledge diffusion. The effectiveness of the ecosystem depends on its ability to adapt and evolve through models such as open innovation, which allows for the open exchange of ideas and technologies between universities and external markets. Therefore, it can be studied in several ways respectively:

As articulated by Chesbrough (2003), the concept of 'open innovation' is a paradigm that recognises that HEIs can benefit from leveraging external and internal ideas and market pathways. It contrasts with "closed innovation."" Closed innovation" is a traditional paradigm in which R&D is internally focussed and the boundaries of the institution are rigid. The shift is a strategic necessity to facilitate the flow of scientific and technological advances from universities to industry and society as a whole. By adopting an 'open innovation' approach,

universities can realign their mission and emphasise the importance of collaboration with industry and community partners.

An "innovation strategy" within the university is critical in defining the roadmap and framework for technology transfer. It guides HEIs on how to foster creativity, manage intellectual property, and effectively collaborate with external entities. Alhajaj (2018) emphasize the importance of a well-structured innovation strategy, which is aligned with the university's overarching goals and objectives and promotes a more streamlined and efficient technology transfer.

The 'services' provided by HEIs, such as research facilities, counselling and continuing education, consolidate the ecosystem by providing tangible means for knowledge and technology diffusion. As Etzkowitz and Leydesdorff (2000) point out, these services are the conduits through which HEIs translate academic research into practical applications.

'Connections' in the ecosystem, which include networks with alumni, industry, government and non-governmental organisations, are critical to the exchange of knowledge and resources. According to Powell et al (2005), the strength and density of these networks can greatly affect the speed and scope of innovation diffusion.

'Inclusiveness' in the technology transfer ecosystem ensures that the benefits of innovation and opportunities for collaboration are available to a wide range of stakeholders. Such inclusiveness can be seen in efforts to engage underrepresented groups in research and entrepreneurship, the value of diversity in driving innovation.

In addition, the ability to 'empower narrow environments', or niche areas in the ecosystem, can enable HEIs to specialise and develop unique capabilities that can lead to innovative breakthroughs. As Cooke (2007) points out, specialisation can lead to competitive advantage in specific technologies and knowledge areas.

Finally, 'entrepreneurship' is a driving force in transforming innovative ideas into marketable products and services. O'Shea (2004) argues that faculty and student entrepreneurial activities play an important role in the technology transfer process, and that HEIs often play a key role in supporting start-ups and spin-offs.

Open innovation

University mission

Effective technology transfer is an important aspect of the mission of the modern university. The first adjustment that universities need to make is to prioritise technology transfer as a core

aspect of their mission. Traditionally, the main mission of universities has been to advance knowledge through research and teaching. However, with the increasing importance of technology transfer, universities must recognise that they also have a responsibility to ensure that the results of their research are translated into practical applications that have a positive impact on society. Universities should therefore allocate resources, staff and infrastructure to support technology transfer activities and to create an ecosystem that promotes innovation and entrepreneurship.

The second alignment is to enhance communication between stakeholders involved in technology transfer. Universities must work closely with industry partners, government agencies and other funding sources to identify commercialisation opportunities and to ensure that research results are relevant to industry needs. Effective communication is essential to ensure that all parties involved have a common understanding of the technology, its potential benefits and pathways to commercialisation. Universities must also communicate with researchers to encourage greater involvement in technology transfer activities and provide incentives to encourage collaboration with industry partners.

The third alignment is the establishment of a well-resourced technology transfer office that provides the necessary expertise and support to execute technology transfer transactions. The technology transfer office should be staffed by experienced professionals with a business, legal or technology transfer background. They should have the necessary skills to identify commercialisation opportunities, manage intellectual property rights, negotiate deals and provide ongoing support to inventors. The technology transfer office should also be adequately resourced to undertake marketing, market research and other activities to promote technology transfer.

Finally, universities must reconcile some of the conflicts that can arise when executing technology transfer deals. For example, there may be a conflict between an academic culture that prioritises research and publication and the commercialisation objectives of industrial partners. Universities must strike a balance between these competing priorities and ensure that researchers are incentivised to engage in technology transfer activities. They must also develop policies and procedures that are transparent, fair and accessible to all stakeholders involved in technology transfer transactions.

In summary, to ensure the smooth implementation of technology transfer, universities must make certain adjustments and changes to their mandates. They must make technology transfer a core aspect of their mission and through the above initiatives, universities can effectively

transform their research results into innovative products, services and solutions that benefit society and drive economic growth.

Close innovation vs. open innovation

The trajectory from closed innovation to open innovation represents a paradigm shift in how knowledge is utilized and disseminated within the technology transfer process, particularly in Higher Education Institutions (HEIs). This transformation is reflective of broader economic and societal trends that have reshaped the innovation landscape.

Closed innovation, historically the bedrock of industrial research and development (R&D), is predicated on a model where firms leverage internal resources and capabilities to innovate. This proprietary approach was encapsulated in the writings of early economists and management theorists who viewed innovation as a linear process tightly controlled within the firm's boundaries. The closed innovation model posited that successful innovation required control — control over the intellectual property (IP), the R&D process, and the market entry of new products or services (Chesbrough, 2003).

However, the advent of the knowledge economy, coupled with a surge in technological advancements, unveiled the limitations of closed innovation. The acceleration of technological change and the concurrent globalization of markets meant that valuable ideas could no longer be fully developed solely within the confines of a single organization. As firms recognized the insufficiency of relying on their internal R&D, the open innovation model emerged as a more adaptable approach, allowing for the absorption and exploitation of external knowledge (Chesbrough, 2003; Alexy & Dahlander, 2013).

In HEIs, the shift from closed to open innovation has been instrumental in redefining the role of universities in the technology transfer ecosystem. The 'Triple Helix' model of university-industry-government relationships highlights the increasing interaction between these sectors, with universities not just contributing to but actively shaping the innovation process (Etzkowitz & Leydesdorff, 2000). The recognition of this expanded role has led universities to establish Technology Transfer Offices (TTOs), dedicated to managing the commercialization of academic research and facilitating the flow of knowledge to industry and society (Siegel, et al 2003).

Despite the opportunities afforded by open innovation, HEIs encounter several barriers in the process of technology transfer. These barriers can be classified as follows:

- *Knowledge Barriers*: There exists a gap between the generation of knowledge within academic institutions and its practical application in the market. This disconnect is often due to the differing objectives of academia, which prioritizes discovery and publication, and industry, which seeks commercialization and profit (Perkmann& Schildt, 2015).
- *Cultural and Communication Barriers*: The difference in cultures between academia and industry can lead to misunderstandings and misaligned expectations. While academics may seek autonomy and the pursuit of knowledge for its own sake, industry professionals are often driven by market demands and timelines (Bruneel et al, 2016).
- *Structural Barriers*: Institutional policies and incentive structures within universities can either impede or facilitate technology transfer. Issues such as IP rights, revenue-sharing agreements, and bureaucratic processes can create obstacles in the commercialization process.
- *Resource Barriers*: Adequate funding and resources are essential for effective technology transfer. However, limited resources can constrain the ability of TTOs to protect IP, market innovations, and engage with potential industry partners.

As HEIs continue to navigate the complex terrain of technology transfer, they must address these barriers to maximize the impact of their research and contribute effectively to the innovation ecosystem. This requires not only structural and policy changes within the institutions but also a cultural shift towards embracing the principles of open innovation and collaboration.

Innovation strategy

In the context of Higher Education Institutions (HEIs), the formulation and implementation of an innovation strategy are pivotal in steering the direction and efficacy of technology transfer activities. An innovation strategy is not a static document but a dynamic roadmap that aligns with the evolving landscape of technology, industry needs, and societal challenges. It encompasses the identification of key areas of research strength, the management of intellectual property, the nurturing of entrepreneurship, and the fostering of strategic partnerships with industry and government entities.

The strategic approach to innovation within HEIs necessitates an understanding that technology transfer is more than a mere transactional exchange of knowledge and technology; it is a complex process that requires an ecosystem perspective. As articulated by Perkmann et al. (2021), HEIs must develop strategies that not only encourage the commercialization of research

but also facilitate collaborative research and consulting, which can be equally significant channels of knowledge transfer.

A robust innovation strategy recognizes the need for flexibility in managing intellectual property (IP) rights. Effective IP management is a balancing act between protecting the financial interests of the university and ensuring that the knowledge generated is accessible enough to foster further innovation and application in the industry.

Universities are also placing an increased emphasis on entrepreneurship as a key component of their innovation strategy. This entails providing support structures for students and faculty to create startups or spin-off companies, thus serving as a direct conduit for technology transfer. As Wright et al. (2009) note, fostering an entrepreneurial culture within academia can significantly enhance the commercialization of research outcomes.

The collaboration between universities and industry is another cornerstone of an effective innovation strategy. Such partnerships can take various forms, from joint research initiatives to industry-funded chairs and centers within universities. These collaborative efforts can lead to more industry-relevant research and can provide a steady channel for the flow of innovations from university labs to the marketplace.

However, formulating an innovation strategy is not without its challenges. Barriers such as cultural differences between academia and industry, misaligned timeframes and expectations, and the need for consistent funding streams must be addressed. Leydesdorff and Meyer (2006) suggest that overcoming these barriers requires an integrative approach where universities function as proactive agents in the innovation process, aligning their strategies with the needs and dynamics of the broader innovation system.

In conclusion, an innovation strategy in HEIs is a multifaceted endeavour that requires thoughtful consideration of the institution's role within the broader innovation ecosystem. Through a combination of effective IP management, entrepreneurial support, and strategic industry partnerships, universities can enhance their technology transfer capabilities and contribute to economic and societal development.

Barriers to an effective innovation strategy, especially within Higher Education Institutions (HEIs), can be multifaceted and often stem from both internal and external factors:

- *Organizational Culture*: HEIs traditionally focus on knowledge creation and education, and may not always possess a culture that encourages commercialization and innovation. This cultural misalignment can lead to resistance within the institution towards adopting practices necessary for effective technology transfer (Siegel et al., 2003).

- *Resource Constraints*: Adequate funding and infrastructure are critical for innovation. Limited resources can hinder research activities, intellectual property protection, and the commercialization process. This also includes human resources, where there may be a shortage of personnel with the necessary expertise in technology transfer (Markman et al., 2008).
- *Regulatory and Bureaucratic Barriers*: Complex and sometimes restrictive regulations surrounding IP rights can impede the process of bringing innovations to market. Additionally, bureaucratic procedures within universities can slow down decision-making and operational efficiency (Thursby & Thursby, 2002).
- *Mismatched Timeframes and Expectations*: The timescale on which academia operates, with its focus on long-term research, often does not align with industry's need for rapid innovation and commercialization. This can lead to misaligned expectations and lost opportunities for collaboration (Anderson et al, 2007).
- *Communication Gaps*: There can be significant communication barriers between academic researchers and industry practitioners. Academics might not be adept at translating their findings into industry-relevant language, while industry might not fully grasp the potential applications of academic research (Bruneel et al., 2016).
- *Incentive Structures*: The traditional reward systems in academia prioritize publishing over patenting or commercialization, which might not incentivize researchers to engage in technology transfer activities (Perkmann et al., 2021).
- *Intellectual Property Management*: Universities sometimes struggle to effectively manage the IP arising from research due to a lack of expertise or resources, leading to potential innovations not being adequately protected or licensed (Anderson et al,2007).
- *Risk Aversion:* HEIs can be risk-averse institutions, and the uncertainty associated with commercializing research can be a significant barrier. This aversion can manifest in reluctance to invest in the development of potentially marketable innovations (Baldini et al, 2006).
- *Lack of Industry Engagement*: Establishing and maintaining strong industry partnerships is challenging, and without these relationships, it can be difficult for universities to understand market needs and find commercial partners for their innovations (Perkmann et al., 2021).

- *Knowledge Transfer Skills*: Researchers often lack the skills or the desire to engage with industry or to start entrepreneurial ventures, which can prevent the translation of research into practical applications (Grigoriou & Rothaermel, 2017).

Addressing these barriers requires strategic planning, changes to organizational culture, investment in resources and infrastructure, and the development of new policies and incentive systems that align with the goals of innovation and technology transfer. Managing the barriers in the innovation strategy of Higher Education Institutions (HEIs) involves a multi-pronged approach, with various solutions having been proposed and implemented to varying degrees of success. Additionally, while solutions are being put into practice, there still exist gaps in research that need to be addressed to further improve the innovation strategy in HEIs.

Existing Solutions:

- *Enhanced Incentive Structures*: Revising the academic reward system to value commercialization activities alongside teaching and traditional research outputs can encourage more faculty and students to engage in technology transfer (Bercovitz and Feldman, 2008).
- *Entrepreneurial Training*: Providing entrepreneurship training to researchers and students can equip them with the skills necessary to navigate the commercialization landscape (Rothaermel et al., 2007).
- *Interdisciplinary Research Centers*: Establishing centers that foster collaboration across different disciplines can help in developing more market-relevant research and innovations (Siegel et al., 2003).
- *IP Management Support*: Improving IP management through specialized staff training and the development of clear policies can enhance the protection and commercialization of university research (Markman et al., 2008).
- *Industry Collaboration*: Actively pursuing partnerships with industry can facilitate better alignment of university research with market needs and provide a clearer path to commercialization (Perkmann et al., 2013).
- *Government Policy and Funding*: Leveraging government policies and funds aimed at supporting research commercialization can help overcome resource constraints and provide a more stable environment for innovation (Leydesdorff and Meyer, 2010).
- *Technology Transfer Offices (TTOs):* Strengthening TTOs with adequate resources and professional staff can help bridge the gap between academia and industry (Siegel et al., 2007).

Research Gaps:

- *Longitudinal Studies on Policy Impact*: There is a need for more longitudinal research that examines the long-term effects of policy changes on innovation outcomes in HEIs (Bozeman, 2000).
- *Cultural Change Dynamics*: Further research is required to understand how organizational culture in HEIs can be shifted toward a more entrepreneurial ethos and what interventions are most effective (Ranga and Etzkowitz, 2015).
- *Impact Measurement*: Developing better metrics and methods for assessing the impact of university innovations on society and the economy remains a significant gap (Salter and Martin, 2001).
- *Global Collaboration Models:* In an increasingly interconnected world, more research is needed on how HEIs can effectively collaborate on a global scale for technology transfer (Fromhold-Eisebith et al., 2002).
- *Diversity and Inclusion*: Understanding the role of diversity in the innovation process and how inclusive practices can enhance technology transfer is an area that requires further study (Hamilton, 2020).
- *Barriers in Different Contexts*: Much of the research focuses on developed countries, and there is a gap in understanding the unique barriers and solutions in developing countries' HEIs (Kruss et al., 2017).
- *Role of Students*: While the role of faculty is often emphasized, the role of students in the innovation process is less understood and could be explored further (Baldini, 2006).

By addressing these research gaps, policymakers, academic leaders, and other stakeholders in the innovation ecosystem can develop more effective strategies to overcome barriers and harness the full potential of HEIs in technology transfer.

Services

In the intricate landscape of technology transfer, Higher Education Institutions (HEIs) play a pivotal role, facilitating the journey from academic research to commercially viable innovations. At the core of this process is a suite of essential services that underpin each phase of technology transfer, ensuring that academic discoveries reach their full potential and yield societal benefits. These services, while diverse, collectively serve as catalysts that navigate and expedite the technology transfer journey.

Intellectual Property (IP) Management

Intellectual Property (IP) Management stands as the cornerstone of this ecosystem, encompassing the identification, protection, and strategic management of intellectual assets. By securing patents, copyrights, trademarks, and trade secrets, HEIs not only protect innovations but also provide researchers with mechanisms to gain recognition and financial returns, thus encouraging further academic exploration and industry engagement. IP offices within HEIs, often staffed with specialized legal and technical experts, guide researchers through patent filings, prior art searches, and potential infringement assessments, offering a vital layer of support and safeguarding.

Licensing and Commercialization

The transition from IP protection to Licensing and Commercialization is where academic innovations find pathways to the marketplace. Licensing agreements bridge the gap between HEIs and industry, facilitating the practical application of research. Revenue generated from these activities is frequently reinvested into research, fostering a cycle of innovation. Licensing professionals within HEIs assess commercial potential, negotiate agreements, and monitor compliance, ensuring that partnerships yield mutual benefits and maintain alignment with institutional goals.

Spin-off and Startup Support

Some innovations spark the foundation of entirely new enterprises, a process supported through Spin-off and Startup Services. These services foster entrepreneurial initiatives by providing incubation facilities, seed funding, mentoring, and business development guidance, creating an environment where research can evolve into viable, market-ready enterprises. By nurturing these nascent ventures, HEIs expand their impact, contributing directly to regional and national economic ecosystems.

Research Collaboration Facilitation

Research Collaboration Facilitation is instrumental in bridging academia and industry. These services ensure that research aligns with industry needs and promotes mutual objectives, often involving collaboration agreements that define roles, expectations, and shared benefits. HEIs act as brokers, identifying potential industry partners, drafting agreements, and managing joint projects, thereby cultivating an environment of mutual growth.

Market Analysis and Feasibility Studies

The importance of Market Analysis and Feasibility Studies cannot be overstated, as they provide critical insights into the viability of innovations. Utilizing tools such as SWOT analysis and Porter's Five Forces, HEI experts assess market dynamics, helping researchers understand competitive landscapes and market demands. This analysis informs strategic decision-making, ensuring that innovations are poised for success in the marketplace.

Educational and Training Workshops

Recognizing the value of knowledge in navigating the complexities of technology transfer, HEIs provide Educational and Training Workshops. These workshops equip researchers with essential skills in IP management, commercialization strategies, and entrepreneurship, fostering a knowledgeable academic community capable of engaging effectively with industry and regulatory environments.

Networking and Outreach Services

Finally, Networking and Outreach Services connect academia with industry, investors, and other stakeholders, facilitating the collaborative relationships crucial to the technology transfer process. HEIs often organize events such as technology fairs, investor meetings, and academic-industry forums, fostering a network that supports innovation and commercialization.

Together, these services form a comprehensive support system that not only enables the successful commercialization of research but also reinforces the role of HEIs in advancing societal and economic progress. Operating seamlessly behind the scenes, these services embody the infrastructure essential for an effective, impactful technology transfer process within academia.

Connections

The Technology Transfer Office (TTO) serves as an integral hub in the innovation ecosystem, ensuring the seamless flow of information and bridging gaps between academia, industry, and government. For a TTO to effectively navigate this nexus, a robust network of external connections is crucial. Let's delve into the multi-faceted connections under the Technology Transfer Ecosystem framework:

Connections with Authorities

Relationships with regulatory bodies play a pivotal role in ensuring adherence to intellectual property rights, tapping into public funding opportunities, and adhering to regulatory standards.

- Local Government: Local authorities can provide insights into regional policies, growth sectors, and area-specific funding opportunities. They are pivotal for initiatives that align with local developmental goals.
- Central Government: Interactions with central or federal government bodies are essential for understanding nationwide policies, obtaining national grants, and ensuring that technology transfers align with broader economic and developmental strategies.

Ecosystem Links

A dynamic connection with various ecosystem stakeholders can stimulate research, development, and innovation.

- Chambers of Commerce: These bodies offer insights into prevailing business trends, potential collaborations, and opportunities to integrate academic research with market needs.
- Industrial/Service Sector: Direct links with industries or service sectors allow TTOs to understand real-world challenges, ensuring research is market-oriented and impactful.
- Incubators: Incubators nurture early-stage innovations. TTOs can facilitate the transition of academic innovations into startups, benefiting from incubators' nurturing environment.
- Accelerators: Accelerators assist in scaling promising startups. TTOs can collaborate to ensure research-driven ventures gain traction quickly.
- Investors: To commercialize innovations, financial backing is crucial. Having connections with angel investors, venture capitalists, and other funding sources can ensure innovations move from the lab to the market.
- Professional Associations: They offer a platform for networking, knowledge exchange, and understanding industry standards and best practices.
- Other TTOs: Collaborating with other TTOs can lead to shared best practices, joint ventures, and co-development projects.
- Research Institutes: Institutes provide deeper insights into ongoing research, potential collaborations, and avenues for multi-disciplinary projects.

Within these ecosystem links, the nature of the connection can vary:

- Non-existent: No established connection.
- Informal: Connections based on mutual interests without formal agreements. This could be through networking events, seminars, or informal meetings.
- Agreement: Formalized partnerships based on written contracts or Memorandums of Understanding (MoUs). These specify the nature of the collaboration, shared responsibilities, and mutual benefits.

Inclusiveness

The term "inclusiveness" within the technology transfer ecosystem of Higher Education Institutions (HEIs) signifies a deliberate commitment to involving a wide range of individuals, disciplines, and entities in the technology transfer process. This approach fosters a technology transfer environment that is comprehensive, equitable, and representative of diverse perspectives, thereby enriching the innovation landscape with a blend of insights and solutions from across the societal spectrum.

Multidisciplinary Engagement

Inclusiveness in technology transfer necessitates transcending traditional academic silos to encourage collaborations across varied disciplines. By embracing a multidisciplinary approach, HEIs ensure that innovations are shaped by diverse expertise, drawing upon knowledge from the sciences, humanities, and arts. Such a framework broadens the applicability and relevance of technological developments, allowing HEIs to foster initiatives that actively promote interdisciplinary engagement through funding, innovation hubs, and collaborative platforms.

Demographic Representation

Inclusiveness also entails addressing the underrepresentation of certain groups in the innovation domain, such as women, ethnic minorities, and individuals from lower socio-economic backgrounds. Ensuring equal representation and opportunities for these groups enhances the depth of the technology transfer process by bringing forward a holistic spectrum of ideas. Targeted outreach initiatives, mentorship programs, and inclusive policies within HEIs support the participation of underrepresented groups, advancing both equity and innovation.

Engagement of Non-Academic Stakeholders

Inclusiveness extends beyond academia to involve stakeholders such as local communities, industry partners, policymakers, and other non-academic entities. This engagement grounds technology transfer activities in real-world needs and ensures broader societal acceptance. Through community engagement forums, industry partnerships, and advisory boards that incorporate external voices, HEIs can foster a collaborative technology transfer process that is responsive to societal needs and aspirations.

Equitable Access to Resources

A key aspect of inclusiveness is ensuring that resources necessary for technology transfer—such as research funding, IP management, and commercialization support—are accessible to all researchers. Equitable access ensures that promising innovations are not overlooked due to resource constraints. By establishing transparent allocation processes, providing need-based grants, and maintaining accessible support systems, HEIs promote a fair and inclusive technology transfer ecosystem.

Cultural Sensitivity in Tech Transfer

In a globalized context, inclusiveness requires cultural sensitivity to navigate cross-border collaborations effectively. Recognizing and respecting cultural differences facilitates smoother negotiations and fosters respectful partnerships. HEIs can enhance this inclusivity by offering training in cross-cultural communication, engaging cultural consultants, and considering socio-cultural implications in technology transfer strategies, particularly in international projects.

Inclusive Governance Structures

Finally, inclusive governance within HEIs' technology transfer frameworks ensures that decision-making processes reflect a diversity of academic disciplines, demographic backgrounds, and external stakeholders. By establishing governance structures that incorporate a range of voices, HEIs create a more robust decision-making environment, resulting in outcomes that are both equitable and widely accepted.

In summation, inclusiveness within the HEI technology transfer ecosystem is not merely a principle but a pragmatic approach to enhancing the innovation landscape. By fostering a broad-based participation and engagement, HEIs benefit from a richer tapestry of ideas, holistic solutions, and an innovation environment that reflects and serves the broader societal landscape.

Empower narrow environment

In academic discussions surrounding the technology transfer ecology of higher education institutions (HEIs), the term 'narrow environment' commonly refers to the immediate surroundings and the set of localized factors that directly influence the technology transfer dynamics. This can encompass immediate stakeholders, institutional infrastructures, localized cultural norms, and the regional regulatory milieu. Empowering this narrow environment is pivotal for optimizing technology transfer outcomes and ensuring that localized nuances and constraints are adequately addressed.

Stakeholder Capacity Building

The narrow environment is anchored by immediate stakeholders, including faculty, researchers, students, and technology transfer professionals. Their capacity building, through targeted training and resource allocation, is crucial for successfully navigating the intricacies of technology transfer. By offering programs tailored to specific needs—such as IP seminars for researchers or commercialization workshops for students—HEIs equip stakeholders with the tools to engage effectively in the technology transfer process.

Institutional Infrastructure Augmentation

The infrastructural elements within an HEI, including laboratories, research facilities, and technology transfer offices (TTOs), form the operational backbone of technology transfer. Empowering this infrastructure enhances its functionality and accessibility, making it a robust support system for innovation. Prioritizing investments in research facilities, IP management databases, and digital collaboration platforms ensures that stakeholders have the resources they need to drive technology transfer forward.

Localized Cultural Integration

Cultural nuances within the narrow environment, such as institutional values and regional norms, play a significant role in shaping perceptions and behaviors around technology transfer. Recognizing and integrating these cultural aspects into the process can enhance acceptance and engagement. HEIs can achieve this by consulting cultural experts, offering sensitivity training, and fostering a culture that values diverse cultural inputs, creating an inclusive environment for technology transfer.

Adaptation to Regional Regulatory Milieu

The regional regulatory framework, encompassing IP laws, innovation policies, and industry standards, significantly influences technology transfer. Empowering the narrow environment involves maintaining awareness of regulatory shifts and aligning strategies accordingly. HEIs can facilitate this through regular legal workshops, partnerships with regulatory bodies, and maintaining updated compliance systems specific to technology transfer.

Feedback Loops and Continuous Iteration

Empowering the narrow environment requires a responsive approach, incorporating continuous feedback and iterative improvements. By establishing mechanisms for stakeholder feedback—such as periodic surveys, post-transfer evaluations, and data analytics—HEIs ensure that technology transfer strategies remain agile and responsive to the dynamic narrow environment.

Community Engagement and Collaboration

The local community, including industries and public institutions, is integral to the narrow environment. Their engagement ensures that technology transfer activities resonate with local needs and values. HEIs can facilitate town-hall discussions, community-driven innovation challenges, and collaborative projects, aligning technology transfer outcomes with community priorities.

In conclusion, empowering the narrow environment within HEI technology transfer is a nuanced, multi-dimensional process. By deeply understanding and proactively addressing local conditions, HEIs create a supportive ecosystem that enhances technology transfer outcomes and aligns innovations with immediate socio-cultural and regulatory landscapes. As technology transfer continues to evolve, the empowerment of this narrow environment will remain a cornerstone of effective, locally relevant innovation.

Entrepreneurship

Valorization of intellectual assets very often leads to different forms of entrepreneurship. The life cycle starts with ’Idea generation’ – fostering entrepreneurial spirit and supporting business ideas, followed by ’Idea realization’ – mentoring and incubating ideas and teams to deliver first prototypes. It is essential to have a vast network with the ecosystem and cooperation is often realized at events and proper communication.

Entrepreneurship is about the 'why, when, and how opportunities for the creation of goods and services come into existence,' (Shane and Venkatramanan, 2000) and scientific discoveries are a key precursor to this process (Kesting, 2005).

The Bayh-Dole Act of 1980 in the United States prompted universities to set up technology transfer offices to apply for patents and licenses for their research results. It has led to a focus on academic entrepreneurship, also known as university entrepreneurship (Grimaldi et al., 2011). The literature on academic entrepreneurship has mainly focused on how TTOs can foster academic entrepreneurship (Clarysse et al., 2005). Doutriaux (1987) and more recently, Hayter et al. (2021) defined academic entrepreneurship as the creation of new businesses based on university technology by faculty, postdoctoral, students, or affiliates. Others have proposed a broader definition and described academic entrepreneurship as any activity beyond the traditional academic role of teaching and/or personal research (Klofsten and Jones-Evans, 2000), innovative and related to risk factors, directly or Indirect financial rewards to scientists or institutions (Abreu and Grinevich, 2013).

However, these definitions show a field that is still developing, with divergence in core aspects related to the characteristics of academic entrepreneurship itself, the roles of different stakeholders, and the nature of research-based enterprises. Therefore, identifying and enhancing our understanding of the interrelationships between the various elements of innovation and commercialization is an important contribution to the overall knowledge of the field. In this paper, we will use the term academic entrepreneurship to refer to academic staff, including faculty, students and staff from universities and other research organizations, who participate in commercial activities and transfer scientific knowledge to the market in the form of patents, licenses, startup and spin-off creation.

The number of universities providing entrepreneurship support for their students, graduates, researchers and professors is growing. That encompasses both entrepreneurship education, with its two main objectives of generating motivation and attitudes for entrepreneurship and the skills and competencies needed to successfully start-up and grow a business, and the provision of start-up support.

Universities should see themselves as entrepreneurial organisations and environments held together by common values/missions and not detailed control systems. To develop as an entrepreneurial organisation with an entrepreneurial culture the entrepreneurial activities should be established in the strategy. A university should have a working mission statement with an entrepreneurial vision for the future of the institution. In addition, the strategy could have specific objectives for entrepreneurship with associated performance indicators (e.g.

generating entrepreneurial motivation, cognition, and attitudes; generating entrepreneurial competences and skills; support business start-ups; commercialise research results through technology transfers and business start-ups; generate revenues for the institution from spin-off activities; strengthen co-operation between the institution and local firms).

There are many different models for coordinating and integrating entrepreneurial activities across a university. Whichever model is employed, it will take advantage of existing relationships, coordinate across departments, faculties and other centres, and avoid the duplication of work within a university and its local entrepreneurship ecosystem.

Universities play several roles in their communities and one of their key functions is to support and drive regional, social and community development. Universities should be active players, linked to their external environment by having a strong presence in the community. This might include for example, providing facilities to others from outside the institution, participating in regional clusters, supporting local cultural and artistic activities, providing opportunities for regional start-ups or established companies and taking an active role in determining the strategic direction of local development. (EC-OECD Entrepreneurial Universities Framework)

The valorisation of intellectual assets within the domain of higher education institutions (HEIs) has, in recent years, inexorably veered towards entrepreneurship. Indeed, as the global innovation landscape evolves, HEIs find themselves at the crux of an entrepreneurial revolution. To traverse this landscape requires a nuanced understanding of the mechanisms in place, the challenges ahead, and the broader societal implications.

Genesis of Entrepreneurial Ventures in HEIs

Central to this paradigm is the life cycle of entrepreneurial endeavors within HEIs. It commences with the 'idea generation' phase, aiming at fostering an entrepreneurial spirit and buttressing business ideation. It is here that the heart of innovation beats most audaciously, as members of the academic community—be they students, faculty, or researchers—begin to mold abstract concepts into palpable, actionable business proposals. However, the journey from ideation to realization is labyrinthine. It necessitates 'idea realization'—an intricate process of mentoring and incubating these embryonic concepts to fruition, eventually birthing prototypes ripe for commercial exploitation.

Given the nascent entrepreneurial landscape in regions like Ecuador, such endeavors aren't without their hurdles. Bridging the chasm between corporate investment appetites and research-derived business ideas mandates a concerted effort. A synergy between local imperatives and global best practices is the key. Collaborative endeavors with mature

international ecosystems can unlock doors to a plethora of opportunities for startups and entrepreneurs.

Institutional Mechanisms & The Role of HEIs

The overarching institutional strategy invariably gravitates towards strengthening ties within the entrepreneurial ecosystem. A few objectives emerge as critical:

- *Networking and Alliances*: Creating a tapestry of alliances, spanning from local to international, is essential for financing and honing business models. This networked approach fosters a symbiotic relationship between HEIs and the broader entrepreneurial milieu.
- *Promoting a Culture of Entrepreneurship*: Embedding entrepreneurship into the very fabric of academic curricula is pivotal. It calls for a more holistic integration beyond perfunctory courses, making it a transversal theme across faculties.
- *Regulatory Facilitation*: The establishment of institutional regulations that support entrepreneurial pursuits within academic parameters is a crucial enabler.

The Technology Transfer Prism

The evolution of technology transfer in HEIs bears testament to the metamorphosis of academic research. Influenced significantly by legislations like the Bayh-Dole Act of 1980 in the US, technology transfer has matured from a mere contractual exchange to a strategic enterprise. The focus isn't merely on patents and licenses but on the creation of technology-based enterprises. As iterated in the literature, there's a discernible trend towards selling businesses, not just technologies. Such a strategy is not only attractive for the market but also tantalizing for researchers, offering them avenues to see their intellectual pursuits take tangible forms.

The role of Technology Transfer Offices (TTOs) has thus metamorphosed from mere facilitators to proactive strategists. They are the nexus between academic rigor and market pragmatism, ensuring that intellectual assets find their rightful place in the marketplace.

Facilitating the Entrepreneurial Journey

Effective technology transfer is predicated upon various facilitators:

- *Institutional Backing*: From development plans that undergo periodic revisions to earmarked financial support, institutional backing is the bedrock upon which entrepreneurial ventures stand.

- *Research Management*: Clear research regulations, lines of research, and the intertwining of high-level human resources with research ecosystems underscore the importance of managing the research-to-market transition seamlessly.
- *Community Engagement*: Consistent engagement with the ecosystem, be it through conferences, workshops, or social media, is essential. It's not merely about broadcasting; it's about dialogue, feedback, and mutual growth.

In summation, the entrepreneurial pulse within HEIs is resonant and robust. It's a symphony of ideation, realization, and commercialization. However, its harmonious rendition requires an intricate choreography between individual zeal, institutional support, and exosystemic collaboration. As luminaries in the field like Shane & Venkataraman (2000) has illuminated, the bridge between scientific discovery and marketable innovation is entrepreneurship. In this odyssey, HEIs aren't just passive observers; they are the trailblazers, shaping the future of innovation and societal impact.

In examining the Ecosystem-Oriented model (Type 2) within the framework of this dissertation, it's essential to recognize how it extends beyond the conventional triple, quadruple, and quintuple helix models. While these traditional models of technology transfer emphasize interactions among academia, industry, government, and—where relevant—civil society and environmental factors, the Ecosystem-Oriented model represents a more advanced, integrated approach. Rather than simply identifying these stakeholders as collaborative partners, the ecosystem model creates a dynamic, adaptive network that fosters continuous interaction, real-time responsiveness, and co-created value across all sectors. This advanced approach enhances the university's role in TT, viewing HEIs as not just knowledge generators but active participants in a networked innovation ecosystem that supports economic and societal transformation.

Based on this evolution from earlier helix models, the survey questionnaire was meticulously designed to capture elements unique to the ecosystem model, focusing on aspects that go beyond linear, role-based collaborations. It includes questions on the institution's partnership depth and diversity, assessing the breadth and scope of collaborations with industry, government, and civil society in a way that traditional helix models might overlook. While the triple and quadruple helix models highlight static roles of each stakeholder, the ecosystem model assesses how partnerships are embedded into the institution's research and innovation framework, facilitating sustained, meaningful engagement. Questions thus explore the extent

of active industry projects, long-term government collaborations, and even connections with international networks, reflecting the literature's emphasis on adaptive, boundary-spanning partnerships.

The survey also prioritizes questions around entrepreneurial support structures, such as incubators, accelerators, and innovation hubs, which are less explicitly addressed in helix models. While the helix frameworks acknowledge the importance of academia-industry partnerships, they do not fully account for the institutional infrastructure needed to foster innovation at a grassroots level. In contrast, the ecosystem model prioritizes entrepreneurial culture and resource-sharing within HEIs as vital elements for turning academic research into viable products. By gathering data on mentorship programs, venture funding access, and support for student entrepreneurship, the survey evaluates the ecosystem model's commitment to fostering a self-sustaining innovation ecosystem, advancing beyond the helix models' focus on institutional collaboration.

Another unique focus of the ecosystem model, as reflected in the survey, is community and societal engagement. The quintuple helix model introduces environmental and societal considerations, but often as standalone components. In contrast, the ecosystem model treats community engagement as integral to the TT process, ensuring that innovation activities address both local relevance and global impact. The survey, therefore, includes questions on the institution's partnerships with non-profits, local governments, and community organizations, aiming to capture data on the institution's societal contributions and regional impact. These questions allow the dissertation to examine how the ecosystem model facilitates technology transfer that is socially inclusive and responsive to community needs, surpassing the quintuple helix's approach by integrating these considerations into the TT framework.

For elements that require a qualitative understanding beyond structured survey data, such as the institution's approach to sustained regional impact and inclusive innovation, adaptation to changing market dynamics, and long-term scalability of partnerships, focus group discussions provide complementary insights. These discussions delve into the complexities of maintaining diverse partnerships, addressing challenges unique to ecosystem engagement, and balancing local and global demands. Such topics allow for in-depth exploration of the adaptive and integrative aspects of the ecosystem model that traditional helix frameworks may not fully address.

In summary, the literature on the ecosystem model establishes it as a dynamic advancement over the helix models, with an emphasis on sustained, adaptive partnerships and deep societal integration. The survey's structured questions on partnership depth, entrepreneurial support, community engagement, and commercialization infrastructure are grounded in this advanced model, capturing elements that extend beyond the helix frameworks. By pairing these survey data with qualitative insights from focus group discussions, this dissertation provides a holistic evaluation of the ecosystem model's impact on TT, highlighting its ability to meet the needs of a networked innovation landscape while addressing both economic and societal challenges. This integrated approach not only affirms the ecosystem model's superiority over helix models in complex TT environments but also establishes a robust foundation for enhancing HEIs' role in innovation ecosystems.

Changing environment – model/type 3

Unknown challenge

Higher education institutions are increasingly expected to address complex global challenges, such as sustainability, climate change, food security, and social equality. This shift in expectations will require universities to adapt and take on new roles and tasks (Yarime et al., 2012).

a) *Interdisciplinary research*: Universities will need to promote interdisciplinary research to foster innovative solutions for complex, interconnected challenges (Bammer, 2013).
b) *Collaboration*: Increased collaboration between universities, industries, and governments will be essential for driving innovation and addressing these challenges effectively (Etzkowitz & Leydesdorff, 2000).
c) *Education for sustainable development*: Universities will need to integrate sustainable development principles into curricula, providing students with the knowledge and skills to contribute to a sustainable future (Lozano et al., 2015).
d) *Social engagement*: Universities will need to engage more actively with local and global communities, ensuring that their research and innovation activities contribute to social well-being and environmental sustainability (Trencher et al., 2014).

e) *Adaptation of technology transfer processes*: Higher education institutions will need to adapt their technology transfer processes to the new environment by fostering open innovation, enhancing collaboration, and focusing on the development and commercialization of sustainable technologies (Chesbrough, 2006).

Future requirements (barriers)

This section distinguishes between two dimensions of sustainability: sustainable innovations that incorporate environmental and social considerations into their design, and innovations that specifically aim to advance sustainability goals. By employing metrics aligned with the United Nations Sustainable Development Goals (SDGs), this research assesses the effectiveness of different technology transfer initiatives in promoting sustainable development.

Finally, higher education institutions can still function and find their role and position in addressing known and unknown challenges, and in doing so, improve competitiveness, promote sustainable development, and drive innovation in an increasingly interconnected world. This paper has the following recommendations.

Aligning incentives

To enhance competitiveness, higher education institutions should align incentive structures to encourage interdisciplinary research, collaboration, and the pursuit of sustainable development goals (Perkmann et al., 2013). By providing appropriate recognition and rewards for researchers who engage in technology transfer and collaborative activities, universities can foster an environment that drives innovation and contributes to addressing complex societal challenges.

Building capacities

Competitive higher education institutions must invest in building capacity for interdisciplinary research, collaboration, and technology transfer (Siegel et al., 2003). This includes providing necessary resources, infrastructure, and training to support researchers in navigating the complexities of interdisciplinary research and technology commercialization. By building capacity in these areas, universities can enhance their ability to generate impactful research outputs, attract external funding, and strengthen their reputation in the global research landscape.

Strengthening partnerships

To remain competitive, higher education institutions should strengthen partnerships with industry and government stakeholders (Etzkowitz & Leydesdorff, 2000). By promoting the exchange of knowledge and resources, universities can facilitate the co-creation of innovative solutions to complex challenges, driving economic growth and enhancing societal well-being. Furthermore, strong partnerships can enable universities to access additional resources and expertise, contributing to their overall competitiveness.

Effective intellectual property management

Competitive higher education institutions must strike a balance between openness and collaboration, and the protection of valuable research outputs (Hanel & St-Pierre, 2006). Effective intellectual property management is crucial for attracting industry partners, securing funding, and ensuring the successful commercialization of research outcomes. By developing robust intellectual property policies and practices, universities can protect their research investments and enhance their competitiveness in the global research landscape.

Fostering an entrepreneurial culture

Higher education institutions should cultivate an entrepreneurial culture to remain competitive in an ever-changing global landscape (Clarysse et al., 2011). Encouraging researchers and students to engage in technology transfer and commercialization activities can contribute to the generation of new ventures, job creation, and economic growth. By fostering an entrepreneurial mindset, universities can enhance their ability to adapt to changing demands and seize new opportunities, ultimately contributing to their long-term competitiveness.

In summarizing the Changing Environment Model/Type 3, we recognize that higher education institutions (HEIs) are increasingly expected to address critical and complex global issues, including sustainability, climate change, food security, and social equality. Literature on this subject suggests that universities must adapt to these evolving demands, emphasizing the necessity of fostering interdisciplinary research, enhancing collaboration across sectors, and integrating sustainable development principles into both research and education. Studies emphasize the critical role of HEIs in creating knowledge that not only advances science but also addresses societal needs and challenges, demonstrating that a comprehensive approach to technology transfer (TT) within this model requires adaptability and a forward-looking stance.

Literature in this area indicates that aligning technology transfer efforts with such broad societal goals demands that HEIs engage deeply with industry, government, and civil society to develop holistic and responsive strategies. This necessitates expanding traditional TT processes to incorporate open innovation models and flexible frameworks that can pivot with changes in regulatory, economic, and social landscapes. For instance, institutions are encouraged to implement dynamic feedback loops and real-time monitoring systems that capture shifts in market and environmental trends, fostering an adaptive TT ecosystem that is resilient to change.

Based on this literature, the questionnaire survey included questions targeting the adaptability of TT processes within HEIs, such as how institutions align their TT initiatives with sustainability goals and the extent to which they collaborate with external stakeholders to address these societal issues. Additionally, questions explored the integration of environmental considerations into research agendas, focusing on whether HEIs incorporate green technology or socially conscious innovations as part of their TT strategies.

For elements not fully captured within the survey questions, further insights are gathered through focus group discussions, which probe into the institutions' capacity to respond to rapid changes in external demands and their strategies for aligning TT with sustainable development. This multi-faceted approach, combining quantitative survey data with qualitative focus group insights, allows for a nuanced understanding of how HEIs can structure TT models that are not only robust in their current form but also capable of evolving to meet the unknown challenges of the future. This model thus aligns with the thesis's overarching goal: to advance beyond conventional helix models by creating a TT framework that prioritizes real-time responsiveness, sustainable impact, and proactive engagement with complex, dynamic global issues.

Survey

Survey Map

Universidade de Evora	Evora, Portugal	EVORA
Universite Lumiere Lyon 2	Lyon, France	ULL
Universidad del Pais Vasco/ Euskal Herriko Unibertsitatea	Leoia, Spain	UPV/EHU

Escuela Politecnica Nacional	Quito, Ecuador	EPN
Escuela Superior Politecnica del Litoral	Guayaquil, Ecuador	ESPOL
Universidad de Medellin	Medellín, Colombia	UDEM
Instituto Tecnologico Metropolitano	Medellín, Colombia	ITM
Universidad Tecnologica de Panama	Panama City, Panama	UTP
Universidad de Panama	Panama City, Panama	UP
Universidad Autonoma Gabriel Rene Moreno	Santa Cruz, Bolivia	UAGRM
Universidad Autónoma Juan Misael Saracho	Tarija, Bolivia	UAJMS
Universidad de Costa Rica	San Pedro	UCR
Instituto Tecnologico de Costa Rica	Cartago	ITCR
Corporación CIENTECH - Centro de Transferencia De Conocimiento E Innovación	Barranquilla, Colombia	CT
Ini-Novation	Muehltal, Germany	INI

Data collection was conducted through questionnaires, with part of the data coming from focus groups with TTO officials from partner universities and technical institutions by organisation conferences, workshops, other events. Fourteen institutions responded to the questionnaire; therefore, the response rate was 100%. The questionnaire has a total of 109 questions, divided into twelve parts among the 109 questions, there are some questions that didn't get all the answers from all institutions. Thus, all the situations will be considered comprehensively in case some points are missing. The data reported here includes survey data (14 institutions) and focus groups with TTO officials from partner universities and technical institutions (11 institutions in total). Therefore, universities that have not responded to our focus group can obtain some data from the questionnaire.

About Questionnaire Survey

This survey's general objective is to build trust in academic research and in university-industry collaboration by improving the effectiveness of Technology Transfer activities at the Partner Country HEIs. Capacities will be enhanced on three complementary levels, thereby addressing major challenges identified in the target Latin-American countries (Bolivia, Colombia, Costa Rica, Ecuador and Panama).

Academic knowledge and innovative technologies are transferred and used for scientific, technical, socio-economic and commercial purposes through a variety of channels, including:

- publications (technical journals, scientific magazines, etc.);
- presentations and personal contacts (conferences, courses, professional organizations, etc.);
- Intellectual Property management.
- contract research, sponsored research and R&D collaborations with firms;
- institution-industry staff exchange.
- consultancy work by university staff.
- assignment and licensing of technology; and
- spin-offs and start-ups.

Universities seeking to implement an efficient technology transfer activity need a set of policies, tools, culture, and people for effective intellectual property (IP) management and knowledge transfer. The purpose of this survey is to collect information about the TTOs of the partner universities in TETRIS project.

Structure of the survey

The survey has ambitious goals to provide a complex view on TTOs' performance. To cope with the complexity, it has been structured in a way that different sections were designed to cover different areas.

Section 1 – Perception of innovation and technology transfer in higher education

Section 2 – Facts & Figures about the University (general + R&D related)

Section 3 – Research activities at the University

Section 4 – Facts & Figures about IP

Section 5 – Revenue generated from R&D

Section 6 - TT Mechanism - IP Management

Section 7 - TT Mechanism - Research Management

Section 8 - TT Mechanism - Entrepreneurship

Section 9 - TT Mechanism Infrastructure, Professional and Business Services

Section 10 – TT Mechanism – Asset Management

Section 11 – TTO Organisational aspects

Section 12 – TTO Procedures

The primary aim of evaluating technology transfer survey is to impartially assess the efficacy and efficiency of this process, particularly emphasizing its pivotal role in bridging academic institutions with the broader ecosystem. This evaluation endeavours to comprehensively

encapsulate and articulate the myriad factors—under specific prevailing conditions—that are integral to appraising performance. This isn't a quest for a universally 'optimal' solution; rather, it's an exploration of whether Technology Transfer Offices (TTOs) are functioning at their peak or if there's scope for enhancement.

This assessment is designed not as a binary indicator of success or failure but as a nuanced tool for identifying areas where higher education institutions (HEIs) can evolve and adapt. The framework of this assessment is constructed around key principles that serve as its backbone. To operationalize this assessment, we have synergized it with a structured questionnaire. This initial survey, complemented by the responses obtained, is instrumental in fostering a deeper understanding and more accurate interpretation of the technology transfer landscape.

The first section is devoted to investigating the general approach, understanding, scope of the research, development and innovation. Given the dynamic nature of R&D&I's scientific and administrative definitions, which have undergone multiple revisions in recent decades—notably amidst the ongoing paradigm shift towards Industry 4.0—it's pivotal to recognize that uniformity in understanding and approach across various entities is not a given. This diversity in thought and application underscores the importance of examining how different institutions and individuals interpret and implement R&D&I concepts and practices.

In the second through fifth sections, our focus shifts to gathering concrete data and statistics. The objective here is to construct an accurate profile of the Higher Education Institution (HEI) under examination. We aim to understand its scale, the composition and diversity of its programs and faculties, and its role within the local and national educational and research landscapes. This segment serves to contextualize the HEI within both educational-research and local-national dimensions.

The subsequent section is dedicated to research activities, quantifying these endeavours primarily through measurable indicators such as publication count, staff mobility, research engagement, and project involvement. Here, research is viewed as a process of generating intellectual assets.

Following this, the assessment turns to intellectual property (IP) management, focusing on the lifecycle and utilization of intellectual assets post-creation. This segment aims to gauge the extent of revenue generated from R&D&I activities, examining a broad spectrum of IP protection mechanisms, from international patents to know-how. This comprehensive approach helps in identifying aspects of technology transfer practices in every HEI that can serve as a foundation for developing the processes and organizational structures of technology transfer offices.

The next four sections scrutinize existing practices in the four key domains of technology transfer: IP management, research management, entrepreneurship, and professional services. Insights from these areas will be utilized to form a detailed understanding of the current state, which will, in turn, inform the crafting of tailored development scenarios.

These sections serve a dual purpose: they establish a baseline for the current practices and enable the evaluation of the efficiency and effectiveness of improvements made during the development period (i.e., at the project's conclusion).

The final three sections — focusing on asset management, organizational aspects, and procedures — are intricately linked to the core activities of technology transfer. The primary aim here is to collect comprehensive data that informs strategic planning and helps position these core activities within the HEI's organizational framework.

As outlined, the primary objective of the survey is to provide a foundational assessment tool, enabling decision-makers to devise bespoke roadmaps for evolving and enhancing the processes and organizational aspects of technology transfer at their institutions. It's important to note that this assessment guideline is dynamic; it can be expanded, modified, or even have certain elements omitted to remain relevant and effective.

Collaborative Group Dynamics in Technology Transfer Workshops

The TETRIS project workshops, exemplified by those conducted in Cartago and San Sebastian, were structured around collaborative group dynamics designed to foster in-depth engagement with the challenges and strategies of technology transfer (TT) in higher education institutions (HEIs). These workshops implemented structured group work and thematic discussions, enabling participants to exchange insights, share institutional practices, and collaboratively develop TT strategies that are sensitive to both institutional and regional contexts.

In these workshops, participants were organized into thematic groups based on their institutional roles and expertise. Each group focused on core domains of TT—such as Intellectual Property (IP) Management, Research Management, Entrepreneurship, and Professional Services—allowing for targeted discussions on specific challenges and best practices in each area. Each group was assigned leaders and rapporteurs to facilitate discussions, ensure structured contributions, and provide consolidated reporting of insights. This structure enabled participants to leverage their diverse backgrounds to address complex TT challenges and identify actionable strategies.

Through this collaborative approach, the workshops generated several critical insights that form the foundation for the dynamic TT model mapping in this dissertation. For instance, the Cartago workshop highlighted the importance of robust IP management systems, emphasizing the need for clear pathways from IP protection to commercialization. The discussions on Research Management underscored the value of developing structured support mechanisms for academic research, which is crucial for enhancing TT efficiency. Entrepreneurship and ecosystem collaboration discussions revealed the necessity for innovation hubs and external partnerships, showing that TT cannot thrive without strong ecosystem engagement. These insights collectively point toward the need for TT frameworks that are flexible, context-sensitive, and capable of responding to the specific demands of each HEI.

Feedback from these sessions confirmed that the group work not only facilitated knowledge exchange and skill development but also strengthened cross-institutional partnerships, providing a basis for more unified and adaptable TT models. The workshop reports underscore that this structured group methodology allowed institutions to learn from each other's strengths while recognizing areas needing improvement. This collaborative setup also highlighted the importance of continuous improvement, setting the stage for adaptive, responsive TT models.

The information gathered from these workshops serves as a critical precursor to the subsequent chapters. By addressing each TT component—IP management, research strategy, entrepreneurial support, and ecosystem collaboration—the following sections will build upon the foundational insights obtained in the workshops. Each component discussed in the workshops aligns with a corresponding aspect of the TT model that is explored in detail in the upcoming chapters. This approach ensures a logical progression in the dissertation, where the theoretical and practical discussions in each chapter build cohesively on the insights derived from the collaborative dynamics in the TETRIS workshops.

In conclusion, the collaborative group dynamics in these workshops provided not only a platform for participants to shape the TT framework but also key insights into the specific needs and strategies for effective TT implementation across different HEIs. The following chapters, drawing directly from these foundational insights, are structured to address the identified needs systematically, underscoring the dissertation’s commitment to developing a context-sensitive, adaptive TT model that aligns with institutional priorities and stakeholder

expectations. This progression underscores a strong, logically structured approach that reflects both empirical findings and theoretical foundations.

Initial Assumptions

Number	Concepts
1	Concerning R&D a distinction is made between basic, applied and experimental research (prototype, proof of concept). Technology transfer only focuses on applied research.
2	Applied research refers to creating new products, services or technology
3	R&D includes product development, technology development, strengthening a market position or acquiring new markets, and process or organizational development
4	Innovation is essential for organisations to increase competitiveness or gain competitive advantage
5	Innovation does not necessarily mean the invention of completely new things; a novel combination of existing knowledge can also be considered an innovation.
6	Innovation can only be assessed in terms of sustainability
7	Technology transfer refers to the intentional interaction of two or more people, groups or organisations with the purpose of technology exchange by different mechanisms.
8	HEIs through TTO act as disseminator of good practice and know-how including competency as well as capability building which is essential for successful problem solving
9	TTOs facilitate strong top-down leadership and policies that support and encourage academic entrepreneurship combining entrepreneurial spirit with traditional academic values

1. Table Perception of innovation and technology transfer in higher education

Source: Made by author, data from Tetris

21. Figure Perception of innovation and technology transfer in higher education voting results by different higher educations

Source: Made by author

1. Table and 21. Figure present voting results on perceptions toward R&D, innovation, and technology transfer within HEIs. Using a scale from 5 (yellow, full agreement) to 1 (dark blue, disagreement), the results reveal a consensus, with most HEIs aligning positively (yellow tones) on these issues. This suggests a shared understanding and priority placed on R&D, innovation, and technology transfer. However, institutions like UCR, CT, and Uevora display some variance, indicating skepticism or unique perspectives, potentially due to specific institutional challenges or strategic differences. These variations emphasize the need for tailored strategies that address individual institutional contexts.In summary, while HEIs strongly ag on the importance of R&D and technology transfer, the survey also highlights nuanced differences, underscoring the value of adaptable policies to support the sector's diverse needs.

Also, Psychological factors such as motivation, risk tolerance, and attitudes towards commercialization significantly impact academic engagement in technology transfer. Preliminary interviews suggest that faculty who perceive industry collaborations as aligned with their personal and professional goals are more likely to participate actively. Understanding

these motivational drivers is crucial for developing supportive policies that foster a culture of innovation within HEIs.

Analysis

Empirical analysis

The empirical analysis involves a detailed examination of the survey data（See the appendix for details）, including questionnaire, group discussion, action implementation data, and pilot data collection, providing quantitative and qualitative insights into how institutions manage and execute technology transfer. It includes an assessment of factors such as IP policies, research funding, partnership development, and commercialization strategies. This analysis helps in understanding the correlation between institutional practices and successful technology transfer outcomes. Also, this chapter is served to process model design.

First, the author made a technology transfer approach by different higher education institutions, as we can see in the 2. Table.

UPV/EHU	Through a self-developed BI Dashboard
UTP	Internal Management
UCR	PROINNOVA's staff includes 5 people designated as "Innovation Managers", part of their responsibilities is to work with the various lawyers, legal firms, and registry offices for the IP management. Their responsibilities also include executing, enabling and/or supporting the technology transfer activities.
ITCR	Through Liaison Office
UP	n/a
CT	We have a team dedicated to IP coordination, follow-up and monitoring.
UAJMS	Through the Research, Science and Technology Directorate and the research project monitoring unit.
EPN	The TTO analyzes research project proposals to identify potential results that can be protected. This analysis is performed at the time of submitting the proposal and when the results are obtained. Additionally, R&D staff contact the TTO when they have IP requirements.
UDEM	Follow-up meetings, personalized accompaniment to each project, database.

UAGRM	Through internal regulations
ITM	Specialized areas that permanently assess the IP status of identified and protected creations and determine their marketing strategy through third parties. This includes internal management evaluations, IP gazette review, and market research.
UEvora	n/a
ULL	Specific management rules defined at the collaboration agreements.
ESPOL	Through joint work between the Research Dean, the Innovation Department and the R & D & I Commission

2. Table Technology transfer approach by different Higher educations

What we can learn from it and what comment we can get from as below:

The diverse TT approaches across institutions illustrate varying levels of alignment with three core orientations: Strong R&D, Robust Ecosystem, and Adaptability to Changing Environments. Institutions like UPV/EHU, which utilize advanced data analytics through a BI Dashboard, and UCR, with dedicated Innovation Managers, strongly reflect an R&D-oriented approach, emphasizing specialized expertise and structured IP management. This R&D focus is crucial for managing the complexity of intellectual property and strategically positioning research for commercial viability, as supported by Williams and Switzer (2022), who highlight the impact of data-driven strategies on TT agility.

In contrast, institutions such as ESPOL and UDEM exhibit a robust Ecosystem orientation by embedding their TT operations within innovation hubs or entrepreneurship centres, thus fostering strong connections with industry and supporting spin-offs and start-ups. This approach facilitates ecosystem building, creating a supportive infrastructure that nurtures innovation and enables seamless collaboration with external partners. Adams and Lee (2021) suggest that institutions with strong entrepreneurial ecosystems are more effective in identifying and capitalizing on early-stage commercial opportunities, making them well-suited for long-term, sustainable TT outcomes. However, this model requires consistent engagement with industry stakeholders to maintain alignment with market needs, a balance sometimes challenging to sustain.

Institutions like ITM and EPN lean towards Adaptability to Changing Environments, especially those in developmental phases of their TTOs or those with integrated research centres

facilitating TT activities. For these institutions, adaptability is embedded through responsive structures that allow TT strategies to evolve as regulatory, technological, and economic conditions shift. Ferris and Johnson (2021) argue that flexibility in TTOs is essential for young or emerging institutions to develop credibility and build dynamic partnerships over time, especially in rapidly changing sectors. The adaptability orientation aligns closely with evolving TT practices, where continuous feedback and responsive measures are necessary to remain relevant in a competitive landscape.

Collectively, these orientations - R&D-driven specialization, ecosystem-focused integration, and adaptability-cantered flexibility - highlight the multidimensional nature of effective TT practices. Each approach has distinct strengths; however, research suggests that hybrid models, which combine elements from each orientation, may offer the most effective framework. Institutions capable of embedding specialization, ecosystem integration, and adaptability within their TT operations are more likely to foster sustainable, innovative, and resilient technology transfer practices. This balanced strategy, as suggested by Kent and Silva (2022), not only meets current TT demands but also positions institutions to respond effectively to future industry shifts, maximizing both research impact and market alignment.

Based on the previous literature study and subsequent survey results, the author believes that the institutions in the survey can be classified into three categories based on their different characteristics in research and development, ecosystems, and adaptability and competitiveness in changing environments, respectively, as follows:

Category 1: Strong Research and Development Ability

Data Cluster	Indicators
Research Funding Sources	- Total R&D funding received (grants, donations, contracts) - Diversity of funding sources (e.g., regional, national, international)
R&D Income	- Revenue generated from R&D activities (e.g., consultancy services, research contracts)
Research Output	- Number of published research articles - Number of conference presentations - Number of patents filed

IP Management	- Total patents filed - IP protection processes implemented - IP training sessions provided to staff and students
Innovation Strategy	- Support for interdisciplinary research - Degree of alignment between research goals and innovation strategy
Research Capacity Monitoring	- Number of researchers and technical staff involved in R&D - Access to advanced research facilities and technology (e.g., labs, databases)

3. Table Research Development Ability Data Clusters and Indicators

Category 2: Strong Ecosystem

Data Cluster	Indicators
Industry Partnerships	- Number and depth of formal partnerships with industry (e.g., signed agreements, active collaborative projects)
Community Engagement	- Frequency and type of community outreach activities - Number of partnerships with local/regional organizations
Entrepreneurial Infrastructure	- Presence of incubators, accelerators, or innovation hubs - Support services offered for startups (e.g., mentorship, funding access)
Network Density	- Connections with governmental and non-governmental organizations - Extent of interdisciplinary research networks
Inclusiveness	- Programs to engage diverse stakeholders (e.g., underrepresented groups) - Accessibility of resources and opportunities to a broad range of participants

4. Table Ecosystem Situation Data Clusters and Indicators

Category 3: Potential to Maintain Competitiveness in Changing Environment

Data Cluster	Indicators
International Collaborations	- Number of active international research partnerships - Participation in global research networks

Market Responsiveness	- Frequency of updates to research priorities based on industry demands - Degree of alignment with market needs
Sustainability and Adaptation	- Integration of sustainability goals (e.g., alignment with UN Sustainable Development Goals) - Programs focused on climate, social, and economic adaptability
Strategic Partnerships	- Number of strategic alliances with industry and government - Long-term collaboration agreements with external stakeholders
Organizational Agility	- Speed and flexibility in adapting research focus areas - Level of autonomy in decision-making processes
Innovation Culture	- Support for entrepreneurial initiatives (e.g., startup incubators, funding for spin-offs) - Presence of policies encouraging risk-taking and innovation

5. Table Potential to Maintain Competitiveness Data Clusters and Indicators

For the characteristics that appear in the above three categories, the author roughly processed the indicators that can be quantified and obtained the following **Error! Reference source not found.**:

Institution	Research Development Ability	Ecosystem Situation	Potential to Maintain Competitiveness
UPV-EHU	High	Robust	High
UCR	High	Robust	High
UTP	Low	Developing	Medium
UAGRM	Medium	Developing	Medium
ITCR	Low	Emerging	Low
UAJMS	Low	Emerging	Low
EPN	Low	Emerging	Low
UDEM	Low	Robust	High
ITM	Low	Emerging	Low
UEVORA	Medium	Developing	Medium
ULL	Low	Developing	Medium

ESPOL	Low	Developing	Medium
UP	Low	Emerging	Low
CT	Low	Emerging	Low

6. Table Institutional Scores Descriptive Levels

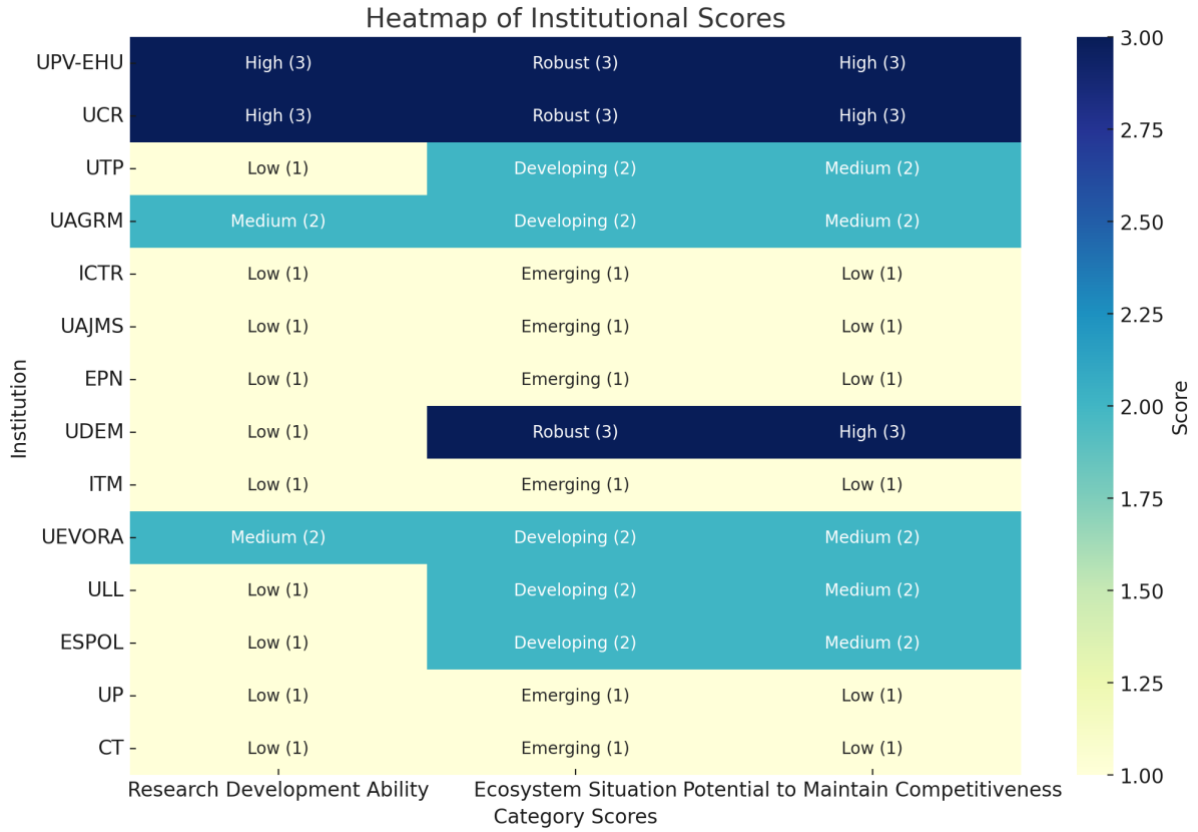
This table outlines the research development ability, ecosystem situation, and potential to maintain the competitiveness of various institutions. The research development ability is categorized as high, medium, or low. The ecosystem situation is described as robust, developing, or emerging. The potential to maintain competitiveness is assessed as high, medium, or low.

UPV-EHU and UCR are rated high in research development ability, have robust ecosystems, and a high potential to maintain competitiveness.

UTP, UAGRM, UEVORA, ULL, and ESPOL have varying levels of research development ability (from low to medium) and developing ecosystems, with a medium potential to maintain competitiveness.

ICTR, UAJMS, EPN, ITM, UP, and CT are rated low in research development ability, have emerging ecosystems, and a low potential to maintain competitiveness.

UDEM stands out as it has a low research development ability but a robust ecosystem and a high potential to maintain competitiveness.



22. Figure Heatmap of TT Model Scores by Institution

In order to represent more intuitively the various capabilities of the above institutions, a heatmap is used to represent the capabilities of 14 institutions in the three dimensions of "R&D Model", "Ecosystem Model" and "Changing Environment". Grouped by institution and the average of the three dimensions. For a comprehensive three-model analysis, the questions or indicators in the survey results should ideally cover a broad range of aspects, reflecting an organization's performance and capabilities in R&D, ecosystem integration, and adapting to a changing environment.

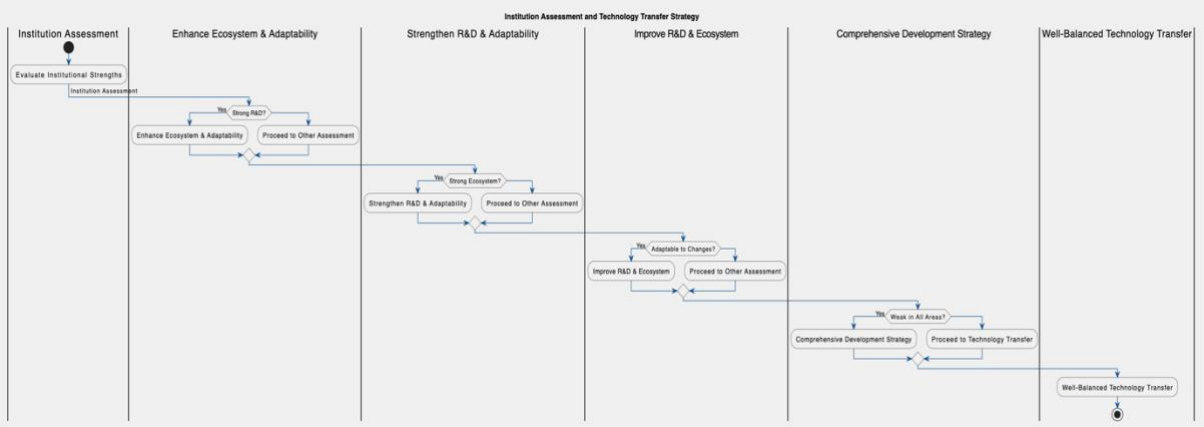
Combining qualitative and quantitative indicators, the university is re-evaluated in the following **Error! Reference source not found.** and the evaluation is revised:

Institution	**Strong R&D (Yes/No)**	**Strong Ecosystem (Yes/No)**	**Adaptable to Changes (Yes/No)**	**Improvement Suggestions**
UPV/EHU	Yes	Yes	Yes	Maintain current strategies, focus on continuous innovation

UTP	No	Yes	Yes	Invest more in R&D capabilities
UCR	Yes	No	Yes	Develop stronger industry partnerships
ITCR	Yes	No	No	Foster an entrepreneurial ecosystem, improve adaptability
UP	No	No	Yes	Strengthen R&D and develop partnerships
CT	No	Yes	Yes	Increase R&D investment, maintain strong IP management
UAJMS	No	No	No	Improve R&D, build ecosystem, enhance adaptability
EPN	No	Yes	No	Strengthen R&D, enhance adaptability to market needs
UDEM	Yes	Yes	No	Improve adaptability to changing environments
UAGRM	No	No/yes	Yes	Invest in R&D, build industry connections
ITM	Yes	No	Yes	Develop a stronger ecosystem for technology transfer
UEvora	No	Yes	No	Enhance R&D capabilities, improve adaptability strategies
ULL	No	No	No	Significant improvement needed in all areas
ESPOL	Yes	Yes	Yes	Continue with current strategies, explore new technology areas

7. Table Institution performance and suggestions overview

Given the classification of institutions by their research development ability, ecosystem situation, and potential to keep competitiveness in a changing environment, the roadmap towards becoming a business process model for technology transfer (TT) institutions can be effectively structured around three strategic axes: Strengthening Core Competencies, Expanding Ecosystem Collaboration, and Enhancing Adaptability and Innovation. This framework balances a focus on internal capability-building with robust external collaboration, while cultivating the agility necessary to respond to evolving market demands and technological advancements.



23. Figure Institution Assessment and Technology Transfer Strategy

As this flowchart provides a nuanced framework for guiding institutions toward a balanced and effective technology transfer (TT) model through a targeted assessment and development strategy. Beginning with an initial institution assessment, it maps out distinct pathways based on institutional strengths and areas needing enhancement. Institutions with robust R&D capabilities are directed to focus on ecosystem engagement and adaptability, while those with a strong ecosystem are encouraged to bolster R&D capacity alongside adaptability efforts. For institutions adapting to changes but lacking strength in both R&D and ecosystem development, the strategy emphasizes building these foundational areas. Finally, institutions identified as needing comprehensive improvement across all dimensions are directed toward a holistic development approach, enhancing competencies across R&D, ecosystem collaboration, and adaptability. Each pathway is designed to progressively lead institutions toward a state of "Well-Balanced Technology Transfer," fostering sustainable impact, responsiveness to market dynamics, and collaborative strength.

Short Description of Actions

Multiple actions implemented to strengthen institutional TT capacities. These actions ranged from capacity-building initiatives, such as training staff in IP management and spin-off creation, to the establishment of Science and Technology Parks (STPs) aimed at fostering collaboration with industry. Research management was enhanced through systematic updates to research policies and improved funding support, while entrepreneurial activities received a boost through initiatives like the STARTUP PhD course, which provided PhD students with the entrepreneurial skills to commercialize their research.

Each action reflects a targeted approach to addressing identified gaps, laying a structured foundation for TT. According to empirical findings, tailored measures like these not only support immediate TT objectives but also contribute to a sustainable knowledge transfer ecosystem by equipping institutions with the resources, skills, and networks needed for long-term adaptability and relevance (Bozeman et al., 2015). The actions are well-suited to prepare institutions for a three-phase TT model that starts with foundational stability (R&D-oriented), expands to broader engagement (ecosystem-oriented), and ultimately fosters a culture of responsiveness (adaptivity-oriented).

Actions by Domain

This section provides an analysis of the specific actions having been taken by institutions in each of the seven key domains of technology transfer (TT): IP Management, Research Management, Entrepreneurship, Asset Management, TT Organization, and TT Processes. These actions reflected the targeted efforts to improve specific aspects of technology transfer based on institutional needs and strategic objectives.

Project title	**IP Mana-gement**	**Research Mana-gement**	**Entre-preneur-ship**	**Asset Mana-gement**	**TT Organi-sation**	**TT Pro-cesses**
Valorisation of technologies	x				x	
Capacity building for the implementation of spin-offs			x			
Science and Technology Parks						

Research Management from Technology Transfer perspective		x				
Analysis of Technology Transfer regulations	x					
Technology Transfer model contracts	x					
Designing Technology Transfer Office	x	x		x	x	x
Strategic Surveillance and Competitive Intelligence		x	x	x		
Entrepreneurial Researchers - STARTUP PhD course		x				
Institutional Strategic Planning in Innovation and Entrepreneurship						
Sources of funding for R&D projects		x				
Entrepreneurship Models			x			
Commercialization of Technologies	x				x	
Design of legal instruments and processes for the creation of a TTO	x					x

8. Table Actions by Domain

7.2.1 IP Management

The actions in IP Management were focused on improving both the tools and the processes used to manage intellectual property (IP). The key elements of IP management include policies, scouting, protection, valorization, training, and supporting tools.

- *Tools for IP protection*: Many institutions, such as EPN and ESPOL, implemented more advanced tools for managing IP, focusing on automating protection processes and

creating structured systems for patent filing and licensing agreements. These actions were taken to ensure research outputs were adequately protected.

- *Training for researchers and staff*: Institutions emphasized training programs to raise awareness of IP-related issues among researchers and staff. For example, ITM and UDEM implemented regular workshops and seminars to educate faculty and staff about the importance of IP management, particularly on topics such as patenting, licensing, and the legal framework surrounding IP protection.
- *Valorization initiatives*: Valorization—the process of turning research into marketable products—was prioritized by institutions like ESPOL, where actions were taken to create clear valorization pathways, helping researchers understand how their work could be commercialized.

7.2.2 Research Management

Actions in Research Management were aimed at strengthening the systems that support the entire research lifecycle, from funding scouting to project execution.

- *Enhanced funding scouting*: Institutions such as ITM and UAGRM took steps to improve their ability to scout for external research funding opportunities. This involved setting up dedicated teams or using external consultants to identify and apply for national and international grants. These actions were intended to increase the institution's research income and support more ambitious projects.
- *Improved proposal support*: Many institutions, including ESPOL and UP, worked on improving the support structures for research proposal preparation. This included establishing centralized offices to assist faculty in writing competitive grant proposals, thereby increasing the likelihood of securing funding.
- *Project management tools*: Actions were taken to implement research project management tools that allow for better tracking and oversight of ongoing projects. EPN, for example, implemented software solutions that enable more efficient management of project timelines, budgets, and reporting requirements.

7.2.3 Entrepreneurship

Actions concerning entrepreneurship were designed to foster an entrepreneurial mindset among faculty and students and to create robust support systems for startup and spin-off creation.

- *Idea generation and realization*: Institutions like ITM and ESPOL launched initiatives to encourage idea generation through innovation hubs and incubators. These initiatives

provided a structured environment where researchers and students could develop their business ideas and receive mentorship from industry experts.

- *Ecosystem links*: Strengthening ecosystem connections was a common action, as institutions sought to create stronger ties with industry partners, venture capitalists, and government agencies. UDEM and UP developed partnership programs that connected their faculty with external stakeholders to foster collaborative innovation projects.
- *Entrepreneurial training*: Many institutions, including EPN and ITM, introduced entrepreneurial training programs that focused on providing the necessary business skills for researchers interested in creating startups or spin-offs. These programs included modules on business planning, market analysis, and financial management.

7.2.4 Asset Management

The actions in asset management were focused on improving how institutions monitor and track their intellectual property and research outputs.

- *Monitoring systems*: Actions in this area included the implementation of comprehensive monitoring systems that allow institutions to keep track of their IP assets. EPN and ESPOL introduced systems that automatically log the status of patents, licenses, and other intellectual property, enabling more strategic management of these assets.
- *Record-keeping improvements*: ITM and UAGRM worked to improve their record-keeping processes, creating centralized databases where all research-related documents are stored and regularly updated. These databases facilitate better oversight of intellectual property and allow institutions to monitor the progress of their commercialization efforts.
- *Data analytics for asset management*: Some institutions, such as ESPOL, implemented data analytics tools to analyze the performance of their intellectual property portfolios. These tools help in determining which patents or research outputs have the greatest potential for commercialization and in making informed decisions about where to allocate resources.

7.2.5 TT Organization

Actions in the organizational domain focused on formalizing the structure and operations of TT offices to improve their overall efficiency and effectiveness.

- *Role distribution*: Institutions like ITM and ESPOL worked on clearly defining roles within their TT offices, ensuring that each staff member has specific responsibilities.

This formalization ensures that there is a clear division of labor, which in turn leads to more efficient operations.

- *Budget allocation*: Actions were also taken to improve budget allocation for TT activities. EPN and UP established dedicated funding streams to support TT operations, allowing their TT offices to expand their services and take on more ambitious projects.
- *Career and professional development*: Several institutions focused on career development for TT staff, recognizing the need for skilled professionals to manage increasingly complex technology transfer processes. ITM and UAGRM implemented professional training programs that provided TT staff with the necessary skills to manage commercialization activities effectively.

7.2.6 TT Processes

The actions in this domain were designed to improve the internal processes that govern technology transfer operations, including task definition, monitoring, and control mechanisms.

- *Task definition and monitoring*: Institutions such as EPN and ITM took steps to clearly define the tasks and responsibilities of each member of their TT offices. This involved creating detailed process manuals and establishing clear procedures for how tasks should be carried out and monitored.
- *Performance monitoring systems*: ESPOL and UAGRM introduced monitoring systems that track the performance of their TT operations. These systems allow the institutions to measure the effectiveness of their technology transfer activities and identify areas for improvement.
- *Control mechanisms*: Several institutions, including EPN and UDEM, implemented more rigorous control mechanisms to ensure compliance with institutional policies and external regulations. These actions were designed to reduce the risk of IP mismanagement and to ensure that all TT activities are aligned with institutional goals.

Key Outcomes of Actions by Domain

Across all seven domains, the actions taken by institutions reflect a concerted effort to enhance the infrastructure and processes necessary for effective technology transfer. Whether through improved IP protection, better research management, or stronger entrepreneurial support, these actions have laid the groundwork for more efficient and impactful technology transfer practices.

Institutions are now better equipped to handle the challenges of commercializing research outputs, securing funding, and building partnerships with industry, thereby positioning themselves as key players in the global innovation ecosystem.

Actions by Institutions

In this section, we explore the specific actions taken by individual institutions to improve their technology transfer (TT) practices. Each institution implemented tailored interventions in the key domains of IP management, research management, entrepreneurship, asset management, TT organization, and TT processes. These actions reflect their unique priorities and strategic objectives, allowing us to observe how different institutions adapted their approaches based on their existing infrastructure, capabilities, and external environments.

Project title	**UP**	**UTP**	**ITM**	**UDEM**	**ITCR**	**UCR**	**UAGRM**	**UAJMS**	**EPN**	**ESPOL**	**CT**
Valorisation of technologies	x		x	x	x		x		x	x	
Capacity building for the implementation of spin-offs						x	x				
Science and Technology Parks					x	x	x				
Research Management from Technology Transfer perspective	**x**							x		x	
Analysis of Technology Transfer regulations		x				x					
Technology Transfer model contracts		x				x					

Designing Technology Transfer Office	x	x		x		x	x			x	
Strategic Surveillance and Competitive Intelligence				x					x		
Entrepreneurial Researchers - STARTUP PhD course	**x**			x				x			
Institutional Strategic Planning in Innovation and Entrepreneurship						x					
Sources of funding for R&D projects				x	x	x		x	x		
Commercialization of Technologies			x							x	
Design of legal instruments and processes for the creation of a TTO										x	

9. Table Actions by Institutions

The recent actions undertaken by institutions like EPN, ESPOL, ITM, UDEM, UP, UTP, ITCR, UCR, UAGRM, and UAJMS reflect a structured approach to enhancing technology transfer (TT) capabilities, underscoring a collective commitment to professionalizing TT operations. This drive is evident in the varied but complementary strategies focused on intellectual property (IP) management, entrepreneurship, research project oversight, and asset tracking. EPN's concentrated effort on IP management, specifically in patent filing and licensing processes, coupled with comprehensive training for researchers, signals a significant step towards

strengthening IP protection. The institution's deployment of advanced project management tools for research oversight, as well as centralized systems to monitor IP assets, demonstrates a move toward a well-coordinated TT system. Such measures align with Carter et al. (2020), who emphasize that structured IP frameworks and project management tools are essential for sustainable TT processes, reducing the risks associated with mismanaged research outputs.

Meanwhile, ESPOL and ITM have shown considerable dedication to fostering entrepreneurship and ecosystem engagement by establishing innovation hubs and connecting with external partners, from industry leaders to venture capitalists. ESPOL's strategy of linking research commercialization with strong ecosystem ties, supported by robust IP management pathways, has established the institution as a leader in innovation-driven research. Similarly, ITM has cultivated a culture of innovation, offering incubation support for faculty and student startups, while improving IP protection and asset tracking systems. This ecosystem-oriented approach, which Adams and Lee (2021) describe as essential for TT effectiveness, enhances commercialization opportunities by connecting institutions directly with industry stakeholders and potential investors, thereby creating a fertile environment for translating research into viable products.

For institutions like UDEM, ecosystem engagement has also been prioritized through partnership programs connecting researchers with external stakeholders. The emphasis on collaborative innovation projects and refined TT processes, such as clarified task definitions within the TTO, has resulted in a more efficient TT structure. These partnerships contribute to smoother IP workflows and strengthen TT infrastructure, supporting the professionalization of TT offices across the institution. UP and UAGRM have taken parallel steps in improving research project management and asset tracking. UP’s focus on research project oversight tools and entrepreneurial initiatives fosters a proactive environment for commercialization through startups and spinoffs. By supporting entrepreneurial activities and providing mentorship, UP not only enhances the TT office's function but also strengthens the university's overall ecosystem.

Institutions like UTP have approached TT optimization through structural adjustments, such as clearly defined roles within the TTO and the allocation of dedicated funding streams to expand TTO services. This realignment aligns with findings by Murtha and Keller (2020), who argue that resource allocation and well-defined roles are critical to TT efficiency, particularly when transitioning from foundational to more complex commercialization processes. Similarly, ITCR has enhanced IP management and launched entrepreneurial initiatives to support

ecosystem engagement, helping researchers transition their work into marketable products and services, thereby fostering a stronger culture of entrepreneurship.

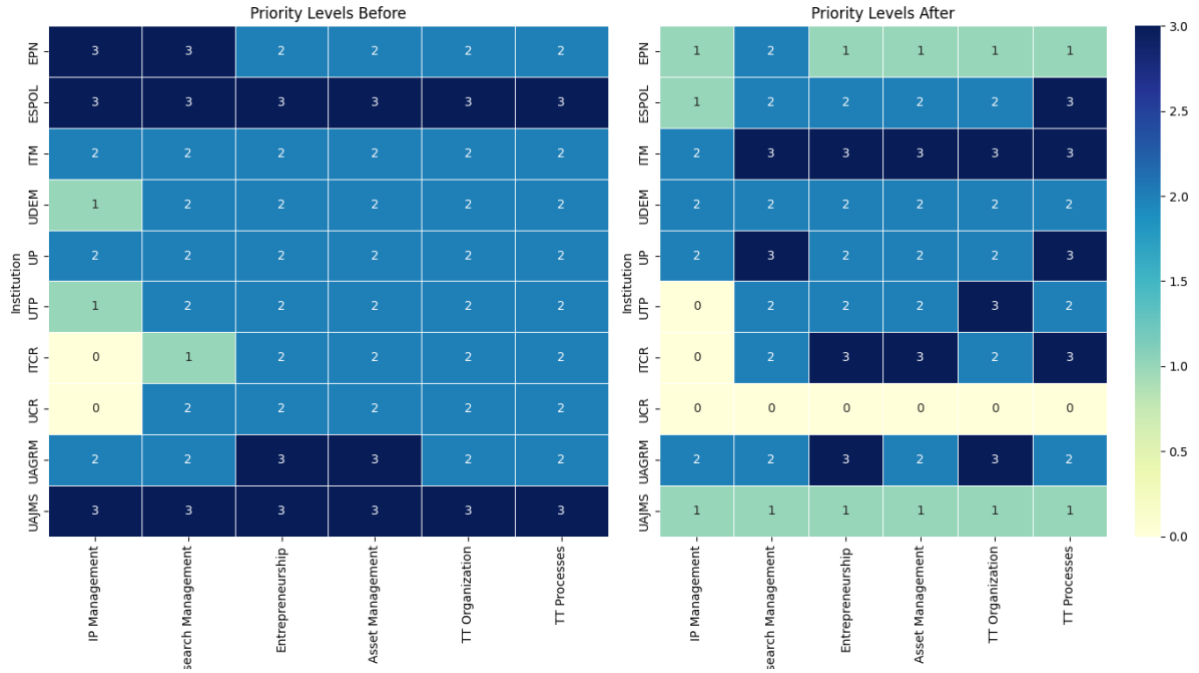
While UCR made strides in IP management by formalizing patent filing and protection processes, the institution faces challenges in fully integrating TT activities with broader entrepreneurial goals. The example of UAJMS also underscores the importance of streamlined internal TT processes. Through refining task management and establishing compliance mechanisms, UAJMS created a more structured environment that supports efficient TT operations, even if broader ecosystem engagement remains limited.

These actions underscore a trend toward professionalizing TT functions and creating integrated systems for managing research, assets, and external engagement. The collective emphasis on IP management and entrepreneurship highlights a growing recognition of the need for balanced TT approaches that support both foundational protection and commercial application. However, to further enhance their TT capabilities, these institutions could benefit from embedding adaptive mechanisms that allow for real-time feedback and responsiveness to external changes, as Jones et al. (2022) suggest. By ensuring that foundational TT structures are adaptable, institutions can better align their TT models with evolving market demands and regulatory landscapes.

This phased progression—from foundational IP management and research oversight to ecosystem engagement and adaptivity—lays the groundwork for a comprehensive mapping model in TT. As institutions advance from internal capacity building to broader industry connections, the mapping model will provide a structured framework that enables universities to balance R&D strength with a supportive ecosystem and adaptive capabilities, creating a resilient TT environment. The integration of adaptive features, continuous monitoring, and feedback mechanisms will allow for a sustainable TT approach that meets both current demands and future challenges, supporting the broader goal of translating academic research into impactful innovations.

Performance comparison analysis before and after the pilot

Aggregated Priorities Before and After



24. Figure Aggregated Priorities Before and After

The comparative analysis of institutional priorities across the seven key domains of technology transfer (TT) reveals substantial shifts following the implementation of targeted TT measures. This shift illustrates a more mature, structured approach to managing TT activities and aligns with broader strategic objectives for research commercialization. Initially, institutions placed significant emphasis on IP management, focusing on developing policies and scouting mechanisms. However, practical aspects of IP protection were often underdeveloped. Post-intervention, priority shifted towards enhancing IP protection and providing comprehensive training for researchers. This transition underscores a move from policy creation to practical implementation, with institutions like EPN and ESPOL prioritizing IP protection as a means to secure and capitalize on research outputs, reflecting a more action-oriented approach to intellectual property.

In research management, the importance of funding scouting and proposal support increased notably, especially at institutions such as ITM and UAGRM. This heightened focus on external funding acquisition and stronger project management support demonstrates a strategic shift towards sustaining research initiatives through external resources. The improvements in proposal support also indicate a growing awareness of the need for structured research project management from conception to completion, allowing institutions to better align research outputs with commercialization objectives.

The domain of entrepreneurship saw a significant transformation, with a marked increase in the emphasis on idea realization and ecosystem engagement. Institutions like ITM and UDEM elevated entrepreneurial activities to high priority, demonstrating a shift towards fostering innovation ecosystems within their organizational structures. This adjustment suggests that institutions increasingly recognize the value of supporting startup formation and nurturing external partnerships as vital pathways for converting research into marketable ventures.

Asset management also gained prominence, with monitoring and record-keeping seeing enhanced prioritization across most institutions. Previously overlooked, asset management now plays a critical role, with institutions like ITM and EPN emphasizing the need for sophisticated systems to monitor intellectual property and track the commercialization potential of research outputs. This shift reflects the growing maturity of TT practices, as institutions move towards more organized and systematic approaches to managing research assets, which is crucial for the long-term sustainability of TT operations.

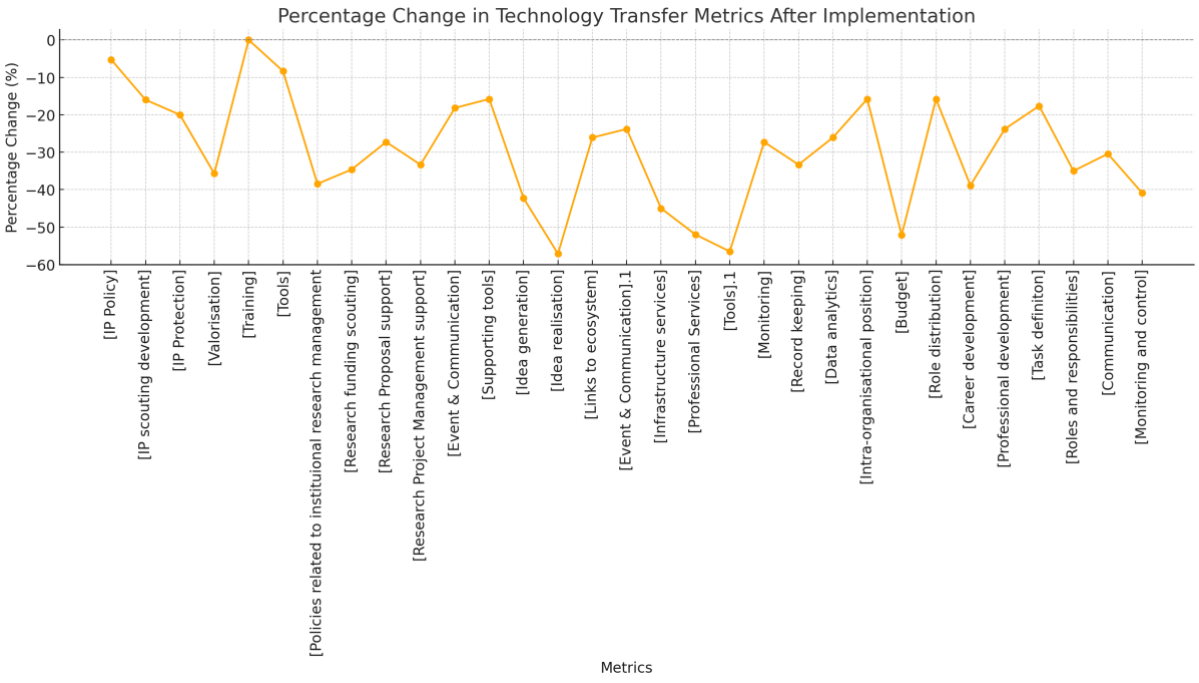
In terms of TT organization, institutions increasingly focused on role distribution and professional development, with EPN and ESPOL assigning higher priority to formalizing the structure and operations of their TT offices. This organizational refinement highlights the recognition that efficient TT offices require clearly defined responsibilities and well-allocated resources. By enhancing the professionalization of TT structures, institutions aim to optimize TT operations and foster a more consistent and efficient pathway for research commercialization.

TT processes, which previously involved only basic task definitions and monitoring, have also undergone significant improvement. Post-intervention, there is a pronounced focus on monitoring and control mechanisms, with institutions like EPN and ITM elevating these aspects to a high priority. This strategic shift towards process refinement aligns with broader trends in institutional professionalization, as structured monitoring and control systems enable institutions to better coordinate the transfer of research outputs, ensuring that all aspects of TT are thoroughly managed.

In summary, the aggregated analysis reveals overarching trends across these institutions, emphasizing a heightened focus on IP protection, research management, entrepreneurship, asset management, TT organization, and process refinement. The shift from policy-focused IP management to robust protection mechanisms reflects a strategic move towards safeguarding

research assets. The increased prioritization of research funding and proposal support underlines the importance of external funding, while the rise in entrepreneurial activity and ecosystem links demonstrates a commitment to fostering innovation and commercialization. Improved asset management practices indicate a recognition of the need for systematic tracking of intellectual property, and the professionalization of TT offices underscores the need for formalized structures to support efficient operations. Finally, the refinement of TT processes through enhanced monitoring and control mechanisms reflects an overarching goal to achieve operational efficiency and effectiveness. Collectively, these shifts signal a deeper institutional understanding of the importance of not only generating research but also securing its protection, facilitating its commercialization, and integrating it into wider economic ecosystems, ultimately supporting a robust and sustainable TT model.

Percentage changes in technology transfer (TT) metrics atfer implementation



25. Figure Percentage Change In Technology Transfer Metrics After Implementation

The graph illustrating percentage changes in technology transfer (TT) metrics post-implementation reinforces the notion of a natural progression in institutional TT priorities. As institutions mature in their TT journey, we observe a structured evolution from foundational activities toward more advanced stages, reflecting the framework of R&D Orientation, Ecosystem Orientation, and Adaptivity Orientation. Each of these stages is characterized by distinct goals and metrics that correspond to increasing levels of institutional TT maturity.

In the R&D-oriented model, the initial emphasis lies in establishing core foundations, including IP management, research policies, and structured IP scouting. The graph shows a decline in priority in areas like "IP Policies" and "IP Scouting," suggesting that these foundational practices have achieved stability. This shift does not signify neglect but rather the successful institutionalization of these elements, reducing the need for continued focus. As these areas become self-sustaining, resources can be reallocated to other vital functions, such as training and commercialization, which are essential for preparing research outputs for market alignment. This transition aligns with the strategic shift toward growth and impact, reflecting a maturation in internal capacities.

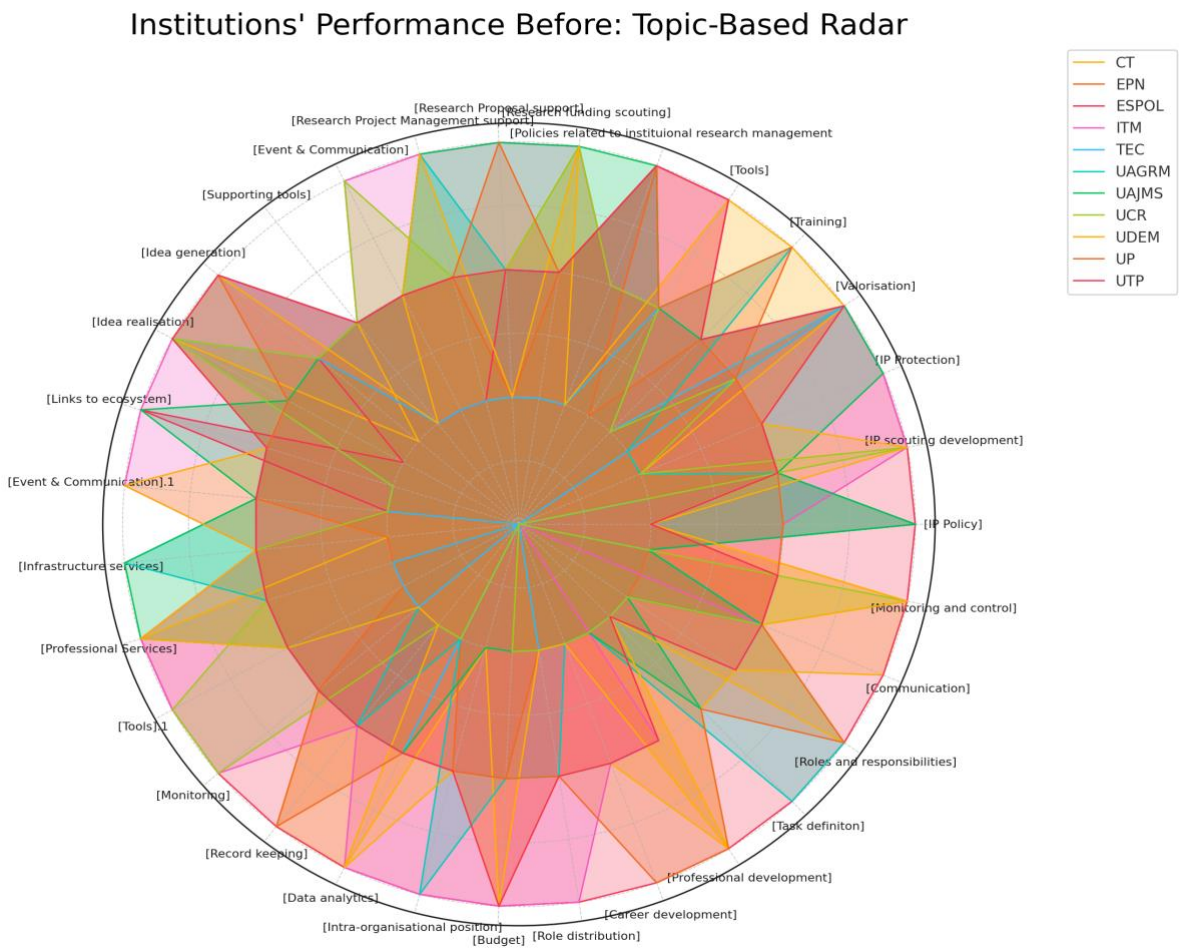
As institutions progress, they adopt an Ecosystem-oriented model, where the focus shifts to external collaboration and entrepreneurial development. This stage emphasizes fostering partnerships with industry, supporting commercialization efforts, and nurturing entrepreneurial ventures. The reduced emphasis on internal IP prioritization visible in the graph corresponds to a strategic pivot: institutions increasingly rely on ecosystem networks to support commercialization and business formation. This shift towards external engagement demonstrates a maturing TT system, where institutions are now capable of leveraging their ecosystems to create value, foster innovation, and scale research outcomes. This model thus reflects a dynamic expansion from foundational stability to an outward-looking, impact-driven TT approach.

At the same time, in the Adaptivity-oriented model, the emphasis is on cultivating resilience and responsiveness to external changes, including regulatory updates, market shifts, and technological advancements. Increased priority in metrics like "Monitoring and Control" on the graph highlights a commitment to adaptability, with institutions investing in systems that monitor changes and enable rapid adjustments in strategy. By focusing on monitoring and adaptive processes, institutions prepare themselves to navigate and thrive amidst external uncertainties, fostering a sustainable TT environment that remains agile and aligned with market demands.

This observed sequence of priority shifts across the three models captures an institution’s TT journey from policy-heavy, internally focused practices to a flexible, ecosystem-engaged framework that dynamically responds to market needs. Mapping institutional TT maturity through the R&D, Ecosystem, and Adaptivity orientations provides a comprehensive roadmap for enhancing TT effectiveness systematically. By following this trajectory, institutions

transition from narrowly focused TT functions to a resilient, high-impact TT system that is well-equipped to thrive under external pressures and facilitate sustainable innovation. The decreases in certain priorities within the graph underscore this progress, indicating resource reallocation toward increasingly strategic, value-driven TT activities, which are essential for long-term growth and adaptability.

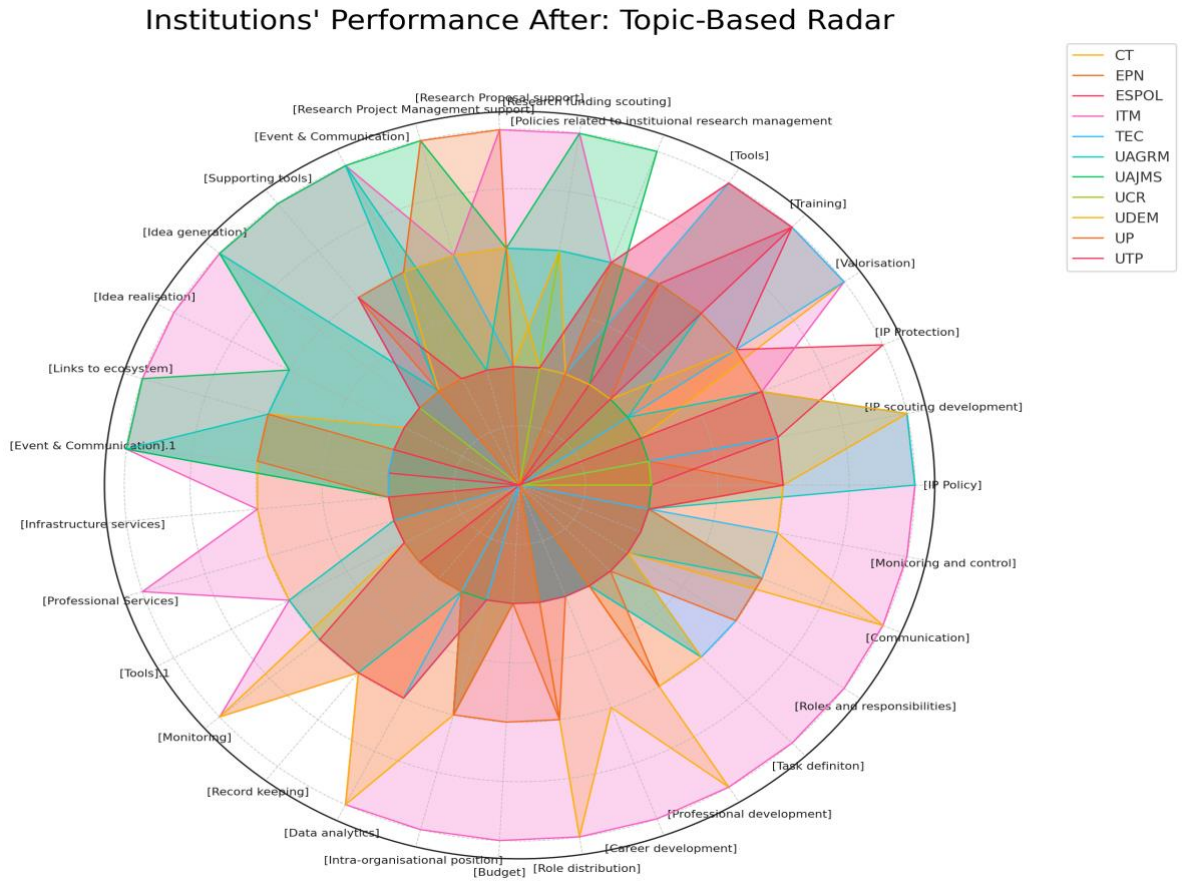
Institutions' overall performance before and after: Topic-based Radar



26. Figure Institutions' Performance Before: Topic-Based Radar (by priority)

The two radar charts provide a comprehensive view of institutional performance across multiple technology transfer (TT) metrics, capturing shifts in emphasis and effectiveness before and after implementing improvement measures. Each spoke represents a specific TT metric, with different colors corresponding to the individual institutions, creating a visual narrative of TT progression.

The "before" radar chart reveals a more diverse but generally lower and less consistent distribution across metrics, indicating variability in foundational capacities among institutions. This chart highlights early-stage focus on core areas such as IP management, research project management, and basic ecosystem engagement, showing that institutions were establishing their TT foundations with varying degrees of success. The relatively dispersed pattern reflects the initial need for building consistent internal processes and establishing baseline TT practices



27. Figure Institutions' Performance After: Topic-Based Radar (by priority)

In contrast, the "after" radar chart shows a more balanced and filled-out pattern, indicating an increase in performance across most TT metrics following the pilot interventions. Higher scores in areas such as ecosystem links, entrepreneurship support, and adaptivity signify that institutions have progressed beyond foundational efforts, moving toward more strategic TT activities that support external engagement and responsiveness to market demands. This convergence on the radar suggests a maturation in TT processes, with institutions now focusing on advanced metrics such as ecosystem collaboration and flexible, real-time monitoring systems.

Overall, the two charts together visually represent the institutional transition from a primarily foundational, internally focused TT approach to a more strategic, externally oriented model. They underscore the shift in priorities and the institutional capacity-building journey, setting the stage for mapping TT models based on R&D, Ecosystem, and Adaptivity orientations, and providing a clear indication of how these orientations foster maturity in TT practices.

Mapping Dynamic Models

The Dynamic Mapping Model chapter captures the evolution of Technology Transfer (TT) frameworks from conventional, research-focused structures to dynamic, ecosystem-driven models that incorporate sustainability and adaptability at their core. This transformation represents a significant departure from traditional TT approaches, such as the triple, quadruple, and quintuple helix models, which primarily emphasize structured collaboration between academia, industry, government, and, in more complex forms, civil society and environmental considerations. The dynamic TT model, however, is an advanced iteration that moves beyond these fixed interrelations, positioning universities as responsive and adaptable agents within the innovation ecosystem.

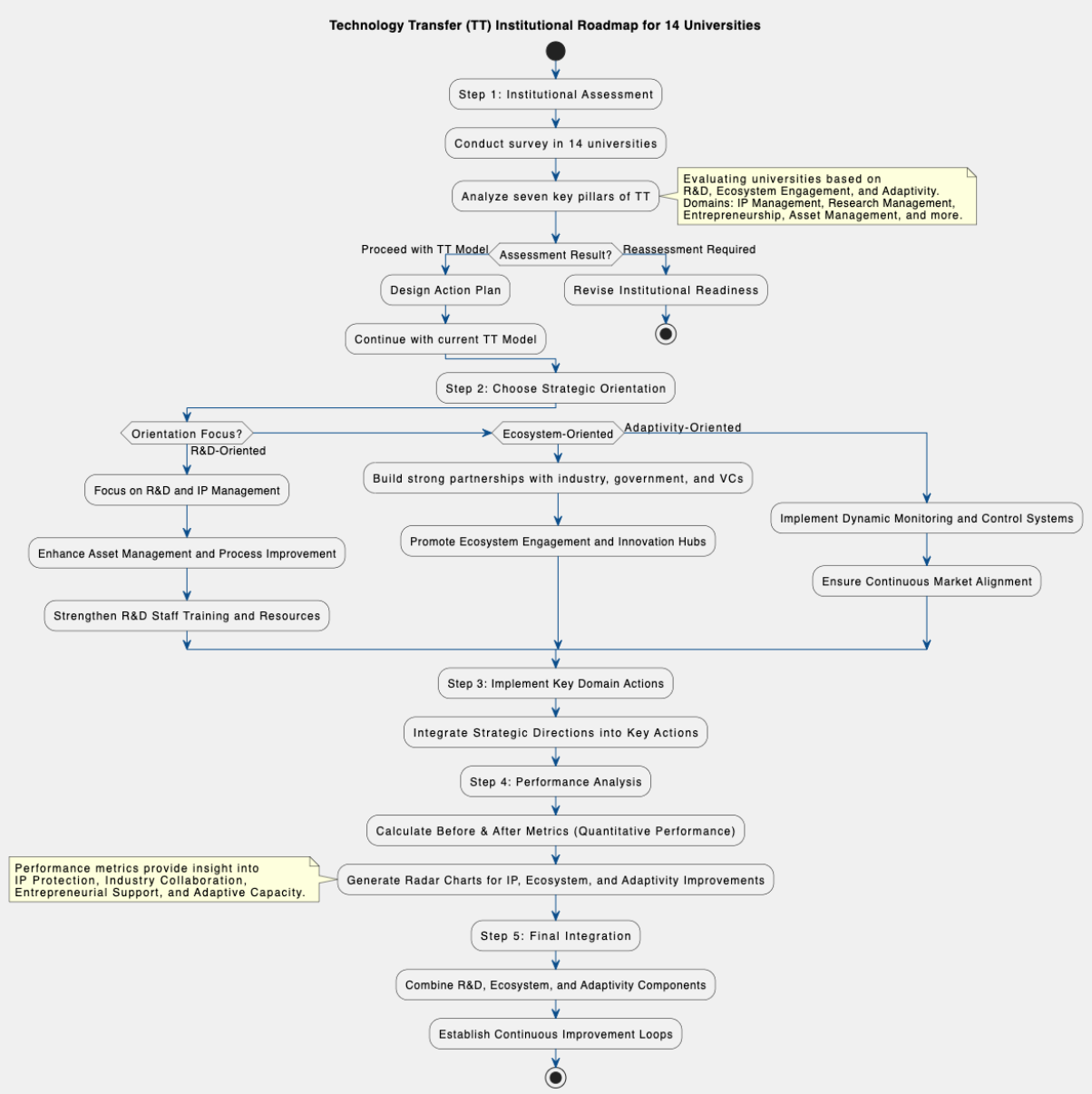
A key element in this model is the integration of ecosystem engagement as a fundamental component of TT success. While earlier helix frameworks established the importance of partnerships, the dynamic model deepens these relationships by incorporating real-time monitoring, data-driven IP management, and responsive feedback systems. Institutions like ESPOL and ITM illustrate how active and strategic engagement with industry, government, and venture capitalists can drive the commercialization of research outputs, ensuring that these outputs are tailored to market needs and societal challenges. This adaptive approach enables universities to shift strategies quickly in response to technological changes and market demands, ensuring that their contributions remain relevant and impactful.

Entrepreneurship also assumes a central role in the dynamic model, reshaping TT from a passive IP protection focus to an active commercialization engine. Unlike traditional helix models, which treat universities as primarily knowledge-generating entities, the dynamic TT model frames them as innovation hubs, equipped with the infrastructure and support systems necessary for startup creation and business development. The establishment of innovation hubs, incubators, and mentorship programs reflects a sophisticated understanding of the university's

role in fostering economic growth. By actively supporting entrepreneurial initiatives, institutions can turn research ideas into viable market solutions, bridging the gap between academia and industry in more impactful ways.

Additionally, the model emphasizes adaptability and flexibility in stakeholder interactions, creating continuous and sustainable integration with both government and civil society. Unlike sporadic partnerships, this model fosters dynamic feedback loops, facilitating policy alignment, social relevance, and environmental responsiveness. This continuous improvement ensures that TT processes remain sensitive to societal needs and regulatory changes, enabling institutions to address complex global challenges effectively. The model's capacity to incorporate environmental considerations, such as green technology and sustainability goals, allows universities to contribute meaningfully to pressing societal issues, making them key players in the pursuit of sustainable development.

In essence, the dynamic TT model represents a comprehensive, next-generation framework that builds on and surpasses the helix models. By emphasizing adaptability, real-time engagement, proactive entrepreneurship, and societal integration, this advanced model positions higher education institutions to address the complexities of a globalized knowledge economy. As universities adopt this dynamic approach, they not only enhance their commercialization capabilities but also strengthen their role in driving societal and economic growth, offering a transformative blueprint for future technology transfer practices.



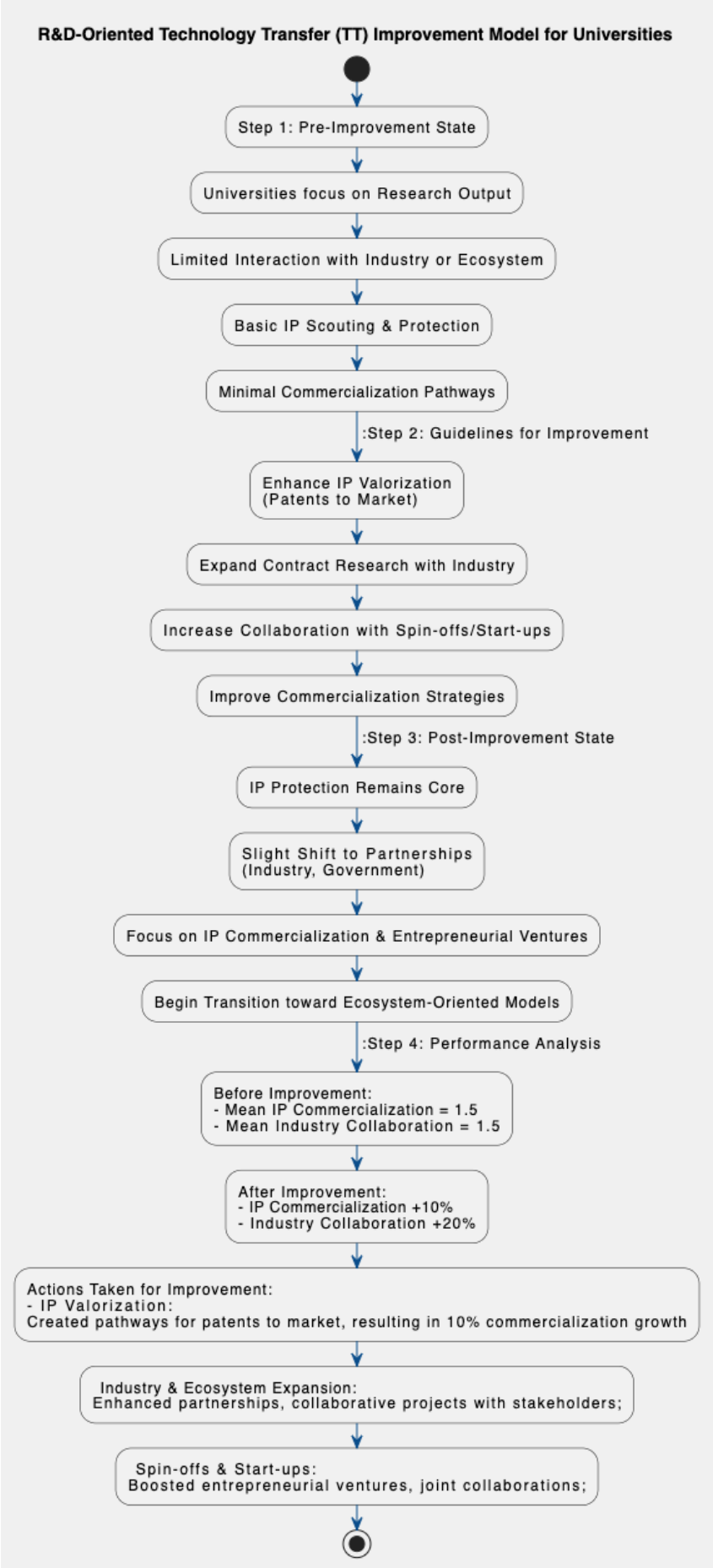
28. Figure Technology Transfer (TT) Institutional Roadmap for 14 Institutions

The "Technology Transfer (TT) Institutional Roadmap for 14 Universities" chart provides a structured, multi-step framework for evaluating and enhancing the TT capabilities of institutions based on their existing strengths and developmental needs. The process begins with a comprehensive assessment, evaluating key pillars such as industry partnerships, IP management, and adaptability to dynamic market conditions. From this assessment, institutions are directed down one of four primary pathways, each designed to strengthen specific areas critical to TT success.

For institutions with robust R&D capabilities, the roadmap emphasizes ecosystem enhancement and adaptability improvements to foster a more collaborative and resilient TT environment. Those with established ecosystems are encouraged to expand their R&D capacity

and integrate adaptability measures, ensuring they can respond effectively to external shifts. Institutions demonstrating adaptability but lacking in R&D or ecosystem strength are advised to build foundational competencies in these areas to support sustainable TT activities. For institutions with gaps across all dimensions, the roadmap recommends a holistic strategy, reinforcing R&D, ecosystem, and adaptability components to achieve a balanced TT framework.

This roadmap ultimately guides institutions toward achieving "Well-Balanced Technology Transfer," which combines strong internal capabilities with external partnership strategies, adaptability, and responsiveness to market demands. Each step is informed by empirical data, aligning with the comprehensive TT models, and suggests that institutions equipped with a blend of R&D expertise, ecosystem integration, and adaptability are best positioned for enduring impact and innovation within their technology transfer processes.

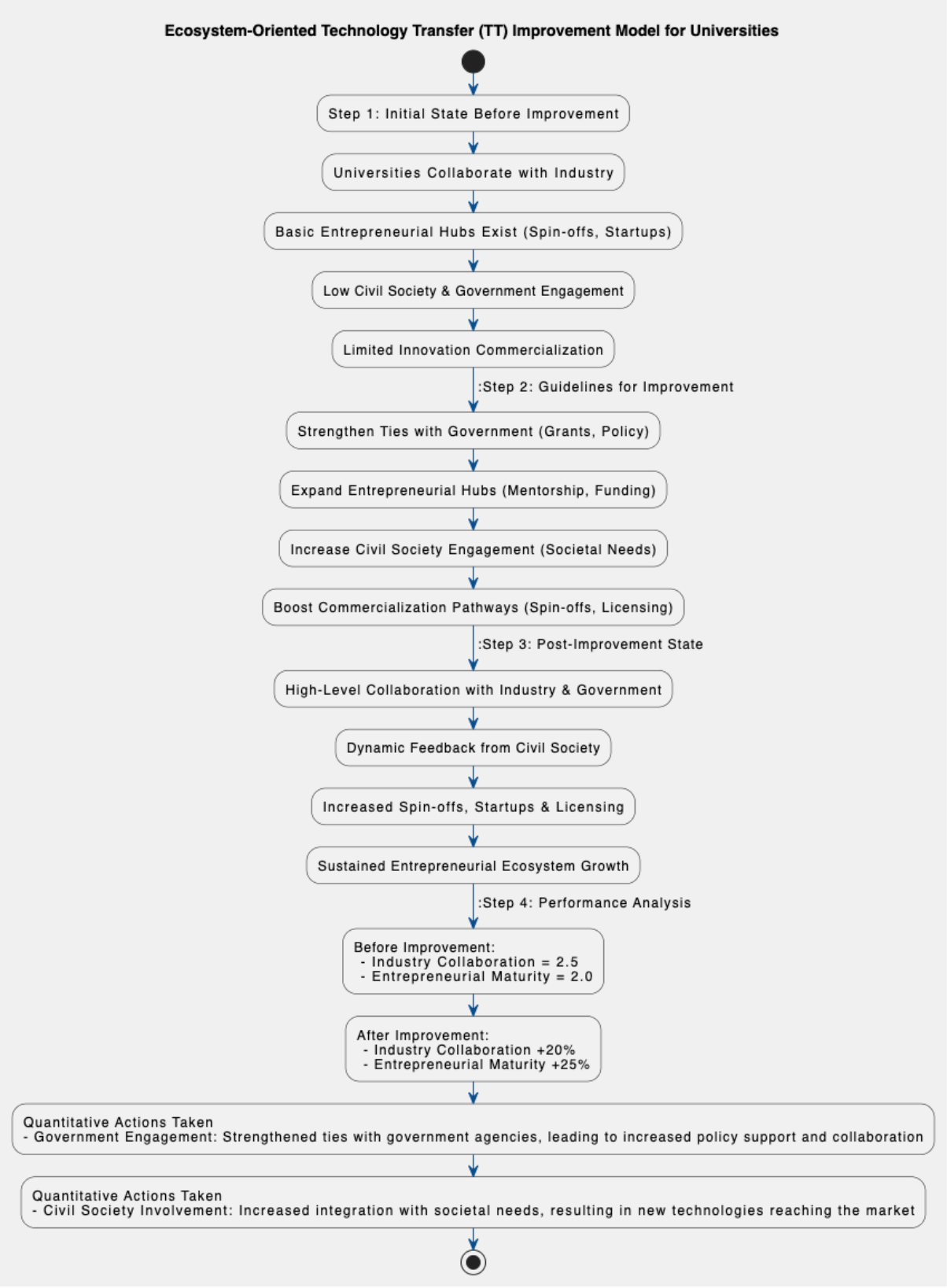

R&D-Oriented Technology Transfer (TT) Improvement Model for Universities
Step 1: Pre-Improvement State
Universities focus on Research Output
Limited Interaction with Industry or Ecosystem
Basic IP Scouting & Protection
Minimal Commercialization Pathways
:Step 2: Guidelines for Improvement
Enhance IP Valorization (Patents to Market)
Expand Contract Research with Industry
Increase Collaboration with Spin-offs/Start-ups
Improve Commercialization Strategies
:Step 3: Post-Improvement State
IP Protection Remains Core
Slight Shift to Partnerships (Industry, Government)
Focus on IP Commercialization & Entrepreneurial Ventures
Begin Transition toward Ecosystem-Oriented Models
:Step 4: Performance Analysis
Before Improvement:
- Mean IP Commercialization = 1.5
- Mean Industry Collaboration = 1.5
After Improvement:
- IP Commercialization +10%
- Industry Collaboration +20%
Actions Taken for Improvement:
- IP Valorization:
Created pathways for patents to market, resulting in 10% commercialization growth
Industry & Ecosystem Expansion:
Enhanced partnerships, collaborative projects with stakeholders;
Spin-offs & Start-ups:
Boosted entrepreneurial ventures, joint collaborations;

29. Figure R&D-oriented Technology Transfer (TT) Improvement Model for Universities

The "R&D-Oriented Technology Transfer (TT) Improvement Model for Universities" chart outlines a structured, phased approach to enhancing technology transfer capabilities with a foundational focus on research and development. In the “Pre-Improvement Stage”, universities are positioned in a primarily research-focused role, characterized by limited ecosystem engagement, basic IP protection measures, and minimal pathways for commercialization. This stage reflects an early-phase TT model where institutions prioritize safeguarding research outputs without actively engaging industry or exploring commercialization channels. In the “Guidelines for Improvement” stage, institutions are encouraged to expand their focus beyond basic research protection by enhancing IP valuation and exploring commercialization opportunities. Specific steps include strengthening pathways to bring patents to market, expanding contract research with industry, and promoting collaborations with spin-offs and start-ups. These targeted actions aim to create initial channels for knowledge and technology transfer, leveraging industry connections to increase the reach and impact of research outputs. Moving into the “Post-Improvement Stage”, the model observes a gradual shift as universities establish more active partnerships with industry and government entities. IP protection remains essential, but institutions are now focusing on IP commercialization and supporting entrepreneurial ventures. This stage marks the beginning of a transition towards ecosystem-oriented TT models, where partnerships play a crucial role in knowledge exchange and innovation dissemination.

Finally, the Performance Analysis quantifies the impact of these improvements. By comparing mean IP commercialization and mean industry collaboration rates before and after improvements, institutions can measure their progress. For example, a 10% increase in IP commercialization and a 20% increase in industry collaboration signify tangible growth. This quantitative approach offers a standardized method for evaluating TT success, which holds universal applicability, enabling institutions to benchmark their performance and adjust strategies for continued improvement.

Overall, this model serves for universities as a roadmap generating tool, progressing from foundational R&D-focused TT practices to more sophisticated, collaboration-driven approaches, aligning internal research strengths with external ecosystem demands to maximize TT effectiveness and societal impact.



30. Figure Ecosystem -oriented Technology Transfer (TT) Improvement Model for Universities

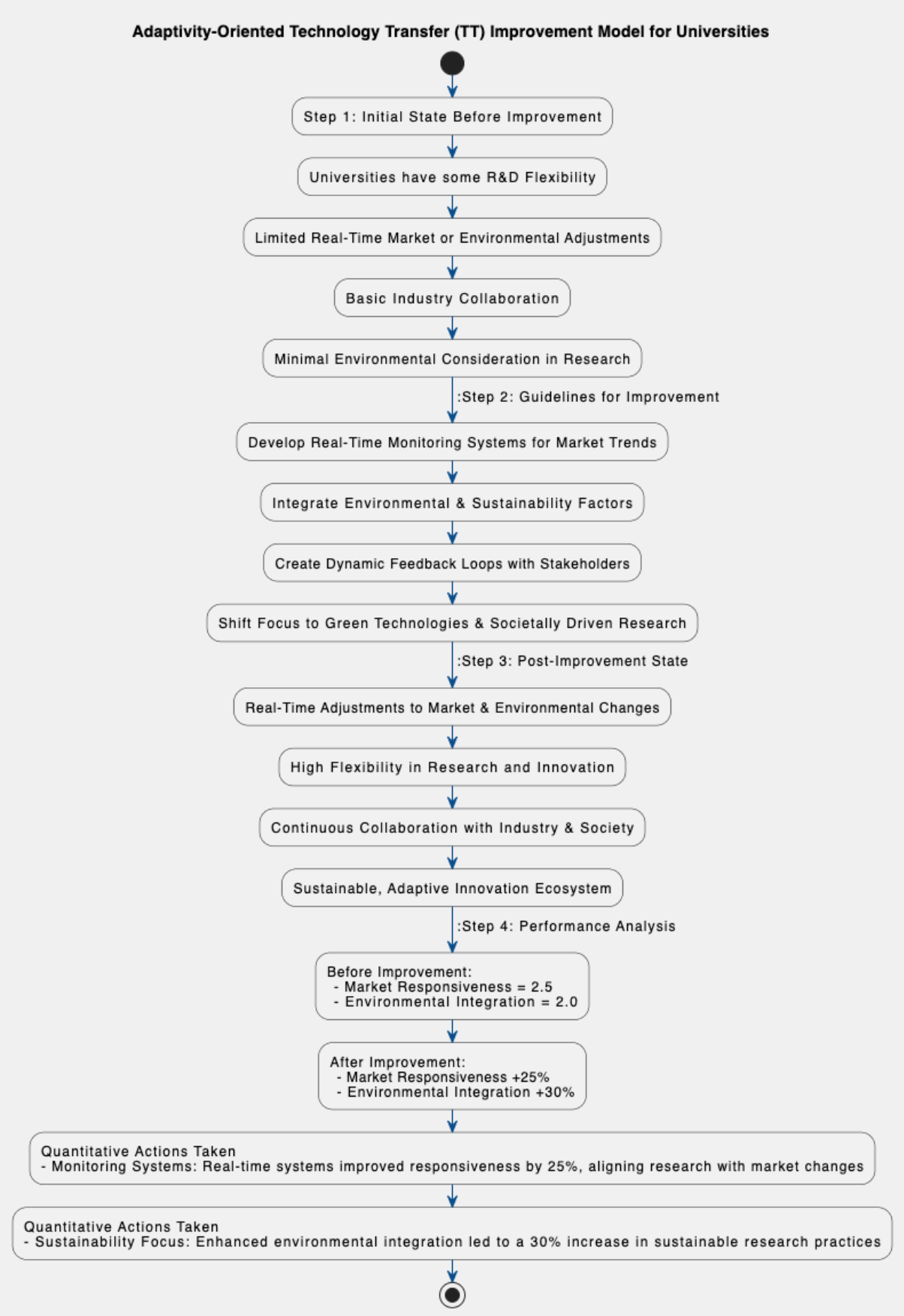
The "Ecosystem-Oriented Technology Transfer (TT) Improvement Model for Universities" chart provides a structured approach for enhancing technology transfer by strengthening collaboration with industry, government, and civil society. Starting from an Pre-Improvement Stage, universities in this stage typically engage with industry but have limited entrepreneurial infrastructure (e.g., basic spin-offs and startups) and minimal ties to government and civil society. Commercialization pathways are underdeveloped, indicating a focus primarily on internal research outputs rather than external engagement.

In the Guidelines for Improvement stage, the model suggests actions to build a robust ecosystem around the university. These actions include strengthening relationships with government agencies through grants and policy collaborations, expanding entrepreneurial hubs that offer mentorship and funding, and enhancing civil society engagement to address societal needs. Additionally, improving commercialization pathways—such as through partnerships with spin-offs and licensing—lays the groundwork for more dynamic TT activities.

The Post-Improvement Stage reflects a more mature ecosystem where the university maintains high-level collaborations with both industry and government, supported by dynamic feedback from civil society. Increased numbers of spin-offs, startups, and licensing agreements indicate a thriving entrepreneurial ecosystem, where sustained growth is now feasible due to reinforced ecosystem support. Civil society's involvement ensures that the innovation ecosystem remains aligned with societal needs, promoting relevance and impact in technology transfer outcomes.

In the Performance Analysis stage, quantifiable improvements are measured. For instance, industry collaboration and entrepreneurial maturity scores show meaningful increases—e.g., a 20% growth in industry collaboration and a 20% improvement in ecosystem maturity. Such metrics provide a standardized way to gauge the effectiveness of the ecosystem-oriented approach, applicable across various institutional contexts. By tracking these metrics, institutions can benchmark their progress, making it easier to refine and scale their TT strategies in line with ecosystem-oriented goals.

This model’s ecosystem-focused progression emphasizes the importance of integrating universities with external stakeholders. It illustrates how a structured enhancement of industry, government, and civil society engagement can transform a university's TT capabilities from isolated research outputs to a fully integrated, societal-impact-driven technology transfer ecosystem.



31. Figure Adaptivity -oriented Technology Transfer (TT) Improvement Model for Universities

The "Adaptivity-Oriented Technology Transfer (TT) Improvement Model for Universities" chart outlines a pathway for institutions to enhance their TT activities by becoming more flexible and responsive to external changes, such as market dynamics and environmental demands. Starting with the Pre-Improvement Stage, universities typically exhibit some degree of R&D flexibility but lack mechanisms for real-time market adjustments or significant environmental considerations within their research focus. Basic industry collaboration is present, yet environmental and sustainability factors are often overlooked.

In the Guidelines for Improvement stage, the model proposes specific steps to increase adaptability. Developing real-time monitoring systems for market trends allows institutions to stay aligned with changing industry demands. Integrating environmental and sustainability factors into research and innovation creates a forward-looking approach, ensuring relevance in a socially conscious market. Establishing dynamic feedback loops with stakeholders further enhances this adaptability, providing insights that allow institutions to pivot research focuses, such as toward green technologies and socially driven innovation.

By the Post-Improvement Stage, universities are equipped to make real-time adjustments in research and innovation, maintaining high flexibility and responsiveness to both market and environmental shifts. Continuous collaboration with industry and society ensures that research remains relevant and impactful, ultimately fostering a sustainable and adaptive innovation ecosystem within the university. This stage represents an evolved TT framework, where institutions are not only responsive but proactive in aligning research agendas with broader societal needs.

The Performance Analysis evaluates the model's effectiveness, quantifying improvements in market responsiveness and environmental integration. For example, post-improvement metrics indicate a 25% increase in market responsiveness and a 30% improvement in environmental integration. This quantification provides a benchmark for institutions, offering a replicable way to assess and adjust their TT strategies based on adaptability goals.

This adaptivity-oriented model exemplifies how institutions can progress from static R&D practices to a dynamic TT approach, where real-time responsiveness and sustainability are embedded into the research ecosystem. By systematically integrating monitoring, stakeholder

feedback, and environmental alignment, universities can cultivate an adaptive TT framework that is not only resilient but also anticipates and meets evolving societal and market expectations.

Conclusion and Suggestions

This thesis provides an in-depth exploration of technology transfer (TT) models across diverse higher education institutions (HEIs), examining how institutions can evolve from traditional research-focused approaches to more dynamic, adaptive frameworks. The study addresses three key questions: How can HEIs enhance their TT processes to better align with external market and societal demands? What specific strategies can institutions employ to optimize their unique strengths within the TT ecosystem? How can TT models be tailored to accommodate diverse institutional environments, from research-intensive universities to those with established ecosystems but limited IP infrastructure?

In response, this analysis offers a nuanced understanding of TT enhancement, underscoring the need for an individualized approach. Institutions with strong R&D capabilities are encouraged to expand their ecosystem engagements and global partnerships, using these external connections to channel their research toward market-ready solutions. Conversely, institutions with robust ecosystems but limited research capacity are advised to invest in cutting-edge research and implement structured IP management systems, laying the groundwork for more sustainable commercialization pathways. The thesis reveals that there is no one-size-fits-all model for TT improvement, as each institution's trajectory is shaped by its internal strengths, external relationships, and the demands of its ecosystem.

The innovation of this work lies in its development of a *Dynamic Mapping Model*, an advanced TT framework that surpasses conventional models like the triple, quadruple, and quintuple helix by integrating adaptability, real-time responsiveness, and proactive entrepreneurial support. While the traditional helix models primarily structure collaboration among academia, industry, government, and—more recently—civil society, the dynamic model expands this framework to incorporate continuous adaptation and a deeper focus on sustainability. This model redefines universities' roles as not only knowledge producers but also as flexible hubs of innovation capable of actively driving societal impact. By building on traditional models while addressing their limitations, this dynamic framework provides a template for future-ready TT models that are both agile and comprehensive, positioning HEIs to respond to rapid shifts in the global knowledge economy.

This research presents a high degree of complexity due to the varied institutional contexts, stakeholder interactions, and structural factors that shape TT practices. Mapping diverse TT models and identifying effective strategies requires a nuanced analysis that accounts for each institution's capacity for research, IP management, entrepreneurial support, and ecosystem engagement. The task is made more challenging by the need to integrate data across institutions with different goals, capabilities, and market alignments, as well as by the rapid evolution of TT practices in response to emerging technologies and shifting regulatory landscapes.

Moreover, the study's commitment to creating adaptable, detailed recommendations that remain relevant in a changing environment amplifies its difficulty. For example, it proposes tailored approaches for high-R&D institutions, such as expanding global networks and aligning research with market-driven needs, while suggesting that institutions with strong ecosystems invest in deeper startup engagement and agile IP strategies. This level of specificity requires a keen understanding of the interplay between institutional characteristics and external market forces, ensuring that each recommendation is both practical and impactful.

Ultimately, the thesis's innovative contributions lie in its dynamic and adaptive TT model, its detailed institutional mapping, and its tailored, context-specific recommendations. These advancements position HEIs not only to better commercialize their research outputs but also to become integral contributors to economic growth and societal advancement, demonstrating the importance of agility, collaboration, and strategic vision in modern technology transfer.

To build upon the insights gained, several recommendations are proposed to further refine and enhance technology transfer practices within higher education institutions. First, maintaining adaptability within TT frameworks is essential; institutions should continue to foster real-time responsiveness to evolving market conditions and societal needs. This can be achieved by continuously updating IP policies, integrating advanced data analytics for commercialization tracking, and leveraging AI-driven tools to identify emerging trends. Such adaptive measures would ensure that TT strategies remain aligned with technological advancements and shifting regulatory landscapes, enabling institutions to stay competitive in an increasingly dynamic environment. This dissertation contributes to the literature by exploring how digital tools facilitate more agile and efficient technology transfer processes within HEIs. Digital transformation has the potential to streamline IP management, enhance cross-sector collaborations, and optimize data-driven decision-making. Furthermore, this study provides comparative analyses of technology transfer models across different regions, highlighting how socio-economic and regulatory contexts influence innovation strategies and outcomes.

Additionally, fostering deeper and more sustained collaborations with external stakeholders, including industry, government, and civil society, is critical. Establishing long-term partnerships rather than ad hoc collaborations can amplify the impact of TT processes, as it allows institutions to co-create value, align research with market needs, and address societal challenges in a more comprehensive manner. Creating platforms for ongoing dialogue and knowledge exchange with these partners would further enhance the institution's role as a hub of innovation, facilitating a seamless transition of research outputs into viable products and services.

Furthermore, investing in entrepreneurial culture within institutions should be prioritized. While many HEIs are enhancing their entrepreneurial support systems, building a robust culture of innovation—one that encourages calculated risk-taking, cross-disciplinary collaboration, and resource-sharing—is crucial. This requires not only physical infrastructure like incubators and innovation hubs but also a mindset shift among researchers, students, and faculty to view TT as a pathway for societal impact, not merely as a commercialization activity.

Despite these recommendations, this study is not without limitations. The diversity of institutional contexts presents an inherent challenge, as the applicability of the dynamic TT model may vary depending on each institution’s unique ecosystem and resources. While the model provides a comprehensive and flexible framework, its practical implementation may require further customization to address specific institutional constraints, such as limited funding, lack of industry connections, or restrictive policy environments. Additionally, the study’s reliance on qualitative assessments may introduce subjectivity, as institutional progress in TT is not always directly measurable and may be influenced by external factors beyond the institution’s control. Future research could address this limitation by developing quantitative metrics for TT efficacy, allowing for a more standardized evaluation across diverse contexts.

Another potential limitation is the rapid pace of technological and market changes, which may outstrip the capacity of some institutions to adapt. While the dynamic model emphasizes adaptability, smaller or resource-constrained HEIs may struggle to keep up with these changes, potentially widening the gap between leading institutions and those with fewer resources. This highlights the importance of policy support and public-private partnerships in ensuring that even smaller institutions can benefit from advanced TT practices.

In conclusion, while this thesis makes significant strides in developing a dynamic, adaptable TT model, its practical application will require ongoing refinement, sector-wide collaboration, and continued support for all HEIs, regardless of their size or resources. By addressing these limitations and building on the recommendations, HEIs can further optimize their role within

the global innovation ecosystem, contributing to economic growth, societal well-being, and technological advancement in a more inclusive and impactful way.

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