TECHNOLOGY TRANSFER PERSPECTIVES: THE KU LEUVEN CASE STUDY

R.J. Steenkamp[1*]

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Contact details
* Corresponding author
rigardtrapsix@gmail.com

Author affiliations
1 Department of Operations Management, University of South Africa, South Africa

ORCID® identifiers
R.J. Steemkamp
https://orcid.org/0000-0003-4748-0817

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ABSTRACT

The technology transfer office (TTO) is central to the Belgian university KU Leuven Research and Development (LRD) department, and is commendable with respect to the challenges of technology transfer. Together with the current industrial revolution, the case study focuses on a contemporary problem with several dimensions.

Background is provided on philosophical perspectives, academic power, technology transfer platforms, and technology readiness. The exemplary characteristics of KU Leuven and evidence of impressive artefacts obtained through personal observation of the LRD are presented. Essentially, the case study explains the primary functions of a multidisciplinary TTO for effective technology transfer to ecosystems, with platforms such as the library, university hospitals, and others.

OPSOMMING

Die beroepsgerigte gevallestudie omvat die tegnologie-oordrag verskynsel vanuit ’n konseptuele en pragmatiese perspektief. In die soeke na die beste-praktykstandaard vir tegnologie-oordrag is die geval van die Belgiese universiteit KU Leuven se Navorsing en Ontwikkeling (LRD) department as maatstaf gebruik. Die tegnologie-oordragkantoor (TTO) is sentraal tot die Leuven navorsing en ontwikkeling departement (LRD) en is voortreflik met verwysing na die uitdagings van tegnologie-oordrag. Tesame met die industriële revolusie fokus die gevallestudie op ’n kontemporêre multi-dimensionele probleem.

Die agtergrond sluit filosofiese perspektiewe in sowel as akademiese mag, tegnologie-oordragplatvorms, en tegnologie gereedheid. Die uitnemende eienskappe van KU Leuven Universiteit en persoonlike observasie van die LRD getuig van verskeie indrukwekkende artefakte. In essensie verduidelik die gevallestudie die primêre funksies van ’n multidissiplinêre TTO vir effektiewe tegnologie-oordrag na ekosisteme met platvorms soos die biblioteek, Universiteit hospitale and andere.

1. INTRODUCTION

Although normative [1], technology connotes different things these days. It only obtains value upon technology transfer to the user. This process of the transfer of technology (ToT) occurs by different means (i.e., market pull or technology push) and not only from university to industry to the user. Technology is a means to an end, and although the term brings to mind various devices, it entails much more. It is industry-specific, and includes practical applications, methods, systems, and devices. Solving different types of problems, it is the product of transferring scientific knowledge for practical use. On the whole, it is the result of humanity attempting constantly to find more efficient ways of doing things and improving methods and processes for quality of life.

An extract from Giannelis [2] provides industry-specific technologies (also noted in the KU Leuven case study) with the notion that each of these technologies evolves and implies technology readiness prior to commercialisation and technology transfer. The types of technologies are categorised as either objects or methods, with each technology going through phases of development, improvement, and termination. The current industrial revolution entails a wide range of tools to upscale agility and speed up lead times for the modern so-called exponential organisation with the ability to use artificial intelligence. Business technology in general comprises a variety of information technologies for digital marketing, data management, enterprise resources planning (ERP), e-commerce, and other web-based applications. Robotics technology, on the other hand, is an interdisciplinary blend of science and technology, combining mathematics and science to develop machines, technology, and software to make intelligent robots.

Other industry-specific examples of our time include quantum technology, a new field of physics and technology based on the principles of quantum physics. Another development is allowing information to be encrypted but not compromised with blockchain technology now also used for a new class of web-based monetary systems. Furthermore, the sophistication of modern robots enables medical industry specialists to diagnose diseases and prescribe the proper treatments for these diseases, which points to the value of robotic assistance for the medical industry.

While technology transfer remains difficult, it has obtained a new meaning in the context of innovation and the current industrial revolution. While this upsurge has multiple reasons, such as an epochal society, it has also come about as a result of the growing triple helix movement, the university–industry innovation network (UIIN), university–business cooperation (UBC), and the growth of entrepreneurial universities. While high-tech companies have always found different ways to create and transfer technology, the modern approach to innovation has a strong focus on networking with universities. This has led to entrepreneurial universities realising their intellectual property (IP) potential and the potential of engagement with industry and government. Consequently, the concept of 'technology transfer office' (TTO) has emerged, pragmatically observed at the KU Leuven in Belgium. The artefacts displayed at their TTO office include super yeast for spicy aromas of beer, the optimisation of an agricultural baler, leading anti-HIV drugs, metal additive manufacturing, flexible food packaging, refined cochlear implants, reduced tyre noise, and software for digital dentistry (more examples are discussed in the case study). In searching for a technology transfer standard, this paper explores the TTO office from different perspectives, and reflects on the exemplary characteristics of the KU Leuven with its multidisciplinary approach.

The next section considers philosophical and other perspectives on technology.

2. TECHNOLOGY PERSPECTIVES

Theories about technology seem to come in the form of broad descriptive and substantive knowledge about an object and practical operative theories concerning the action of how the technology works or is applied. The nature of technology is usually related to its social effects, because the making of things is primarily to the advantage of humanity.

Key figures such as Plato and Aristotle used terms such as 'technique', with their roots in the Greek notion of *techne* (art or craft-knowledge) and how to make objects. Authors refer to Aristotle's doctrine as an early contribution to the philosophy of technology. Briffault [3] and Lloyd [4] also illuminate ancient thought about technology with respect to philosophical reflection. With testimonies from ancient Greece, the theme is clearly as old as philosophy itself. One view was the thesis that technology learns from nature, while a second thought advocated a fundamental ontological distinction between natural things and artefacts. Man-made things came from the extensive employment of technological objects of creation with respect to carpentry, weaving, ceramics, metallurgy, and agricultural technology.

A book review by Stewart [5] on the German philosopher Ernst Kapp (who was the first to produce a work titled *Elements of a philosophy of technology* in 1877) provides perspectives on technology as a theory of culture, and as a technology rooted in humans' instinctual drive to make tools – a faculty that he calls 'organ projection'. According to Kapp, technology refers to the human's ***relationship to*** an object, such as the iPhone. Technology ***is therefore*** the relationship between humans and the world and the precondition for the emergence of both. Thus the focus is on the character of technology in relation to society with respect to science and technology and human–technology relations.

Philosophers' continual considerations of technology are evident. The 'making of humanity' is about the creation of humankind and the creation of the most creative being. Although this in the Christian world-view is the origin of technology, other philosophers may argue about rational evolution (the making of humanity), early Greek thought, and the history of ideas [3]. Notwithstanding the emergence of practical notions such as 'technology as applied science' [7] and 'normative technology' [1], it is interesting to note how the theme has been questioned [8] and thought about [9].

An academic from the Delft University of Technology (known for its triple helix collaborations and technology transfer) believes that the historical evolution of technology perspectives is still present, regardless of technological change. Van der Poel [6] distinguishes three philosophical perspectives on technology and society, namely (1) technology as a human construct (also shaped by human values), (2) technology as an autonomous force (forged by several dimensions) that determines society, and (3) technology as a co-evolutionary perspective on technology and society (where neither of them determines the other).

In addition, Mitcham [10] states the fact that technology makes contemporary society hang together as an economic and cultural force. The author argues that during the past two centuries it has emerged as a discipline concerned with the meaning of technology for society rather than with technology itself. Mitcham [10] calls this type of philosophy of technology a "humanities philosophy of technology" because it accepts "the primacy of the humanities over technologies".

2.1. Technology transfer concepts

Mansfield [11] has identified the forms and resource requirements of international technology transfer. In addition, Lundquist [12] has illuminated the need to manage the potential value of technology for technology transfer, while Cunningham and O'Reilly [13] have provided perspectives on technology transfer in a broader economic and social context that attempt to incorporate the multiple layers of macro, meso, and micro transfer of technology. Research into the different aspects of technology transfer has grown significantly, especially with respect to the macro perspective. Here, the focus is on the effectiveness of policy instruments designed to support effective technology transfer at institutional, national, or regional levels. This aspect relates to the organisation, structuring, and co-ordination of public funding (subsidising R&D investment) to support the exploitation of research outputs for commercial and societal beneficiaries.

There is also a growing focus on the meso and micro aspects of technology transfer, as well as a growing interest in individual actors such as academia, scientists, principal investigators, and policy makers. The importance of the TTO actors comes into play here with support mechanisms, learner management, and other functions with respect to the process of technology readiness and transfer.

The TTO is the heart of the entrepreneurial ecosystem, enabling technology transfer between actors and institutions. The actors (such as authors, academics, and researchers) consider the eco-factors to overcome the deficits. Testing and improving these factors is crucial for the effectiveness of the entrepreneurial ecosystem. Meso- and micro-level themes of technology transfer include university start-up interactions, academic spin-offs, entrepreneurial teams (composition and interactions), learner management, and equity milestones. The challenge for practitioners is to select the potential academic spin-offs that have real commercial potential. The openness of the entrepreneurial team to adapt and persevere for the sake of commercial success is of equal importance.

Concepts of technology transfer from a university (the context of this paper) need knowledge (benchmarks) on the influence, availability, and competence of university structures with respect to spin-off projects (spin-off businesses). To enhance their understanding of the development of spin-off projects, Kolb and Wagner [14] focused on the specific characteristics and interactions of spin-off projects between 2007 and 2013 in a single university setting (similar to KU Leuven). They derived four types of spin-off project with specific needs for each type and target-oriented support mechanisms. Their framework also included flexible support structures and heterogeneity for TTOs to attain a balance between standardisation and specialisation. This micro study yields the rich nuances that underpin technology transfer. Spin-off projects are discussed further in section 7.3.

2.2. Technology transfer companies

While Swiss-American CDMO, Gibraltar Laboratories, and Steris Laboratories are examples of industry-specific (medical and pharmaceutical) technology transfer companies (TTCs), the Yissum case of the Hebrew University of Jerusalem illustrates a case of a multi-industry TTC and the evolution from TTO to technology transfer company (http://www.yissum.co.il). Being one of the top 15 TTCs in the world in revenues, Yissum has partnerships with numerous industry leaders such as Johnson & Johnson, Roche, Merck, Teva, Adobe, and Google [15]. The company promotes technology transfer from university research outputs while maximising streams of income for research, education, and scientific excellence. Its success is based on its autonomy and legal status as a private entity, hiring talent (industry experience and academia), equity, and profit sharing. Its triple helix and UBC comprise the university, government (the Israeli Ministry of Trade and Industry), industry (long-term business partners), researchers (benefitting through patenting and commercialisation), and students (with funding opportunities for their start-up and other entrepreneurial initiatives).

3. BACKGROUND TO THE PROBLEM

Multiple reasons exist for the need for an effective TTO. This section discusses the primary reasons.

3.1. Innovation blindness

Technology transfer has multiple hurdles to overcome. Companies and academia do not easily become leading innovators, and need strategies and support of the highest standard. TTOs can provide a full service to lift ‘innovation blindness’ by assessing and filling the gap for what the individual or group wants to achieve. Successful innovators examine a context and shape the ‘messiness’ that they encounter. They understand the concept of innovation blindness, and apply the innovation essentials. It is useful to think about inventors not as problem-solvers but instead as bundles of solutions who construct problems suited to their unique skills and ideas.

Studies by Leonardi [16,17] indicate that technology concepts play a key role in selecting the set of cultural resources that will be used to develop technological artefacts. Many innovation processes fail because of innovation blindness, since new technology development efforts frequently resemble blind people touching an elephant. New technological artefacts are possible, however, even if innovators never understand the nature of their own blindness. While a certain amount of disagreement about a new technology is useful for producing a better innovation [18], the evidence suggests that insurmountable disagreements result in delays, suboptimal compromises, or failure.

In the light of the reality of innovation blindness, Goffman [19] suggests ‘frames’ to demarcate a set of cultural resources, providing a way to turn a mess into a specific problem that renders it solvable. In addition, De Jong, Marston, Roth and Van Biljon [20] provide a useful set of essentials for reducing the reality of innovation blindness, irrespective of the availability of a TTO or type of innovator. These essentials are: aspire (accept innovation-led growth as absolutely critical with cascaded targets); choose (invest in a coherent, time-risk balanced portfolio of initiatives that are resourced); discover (actionable and differentiated business, market, and technology insights); evolve (create new business models that provide defensible, robust, and scalable profit sources); accelerate (beat the competition with fast and effective development to market); scale (launch innovations in the relevant markets and segments at the right magnitude); extend (win by creating and capitalising on external networks); and mobilise (people are motivated, rewarded, and organised for repeated innovations).

While all of these essentials for innovation are imperative, different types of innovator will use them to various extents. Visionary innovators (with companies driven by a strong leader) may set new rules of the game; yet, they still need the essentials. The same applies to strategic innovators, discoverers, fast followers, and experimenters. To highlight one essential, it is worth noting that organisational structure is not the emphasis, although to mobilise implies clear roles and responsibilities for driving the innovation agenda.

3.2. Technology readiness

The challenge of recognising technology readiness can close the loop for multiple researchers. While technology may be defined and even developed, it might still not be ready for commercialisation. This is where TTOs should assist researchers, since TTOs are strategically located to operate in a large and dynamic triple helix innovation system. Usually (but not exclusively) situated on the main campus of universities, TTOs are recognised as crucial intermediaries in the technology commercialisation process through which university–business cooperation (UBC) configurations converge into distinct archetypes. However, TTO support is not limited to a once-off commercialisation transaction. Part of the agenda is to assist with start-up companies for students, promoting graduate employability as a social responsibility. This can be achieved, for instance, by adding value to research outputs with respect to valorisation and long-term business relations with students. Evidently, the conventional 'publish or perish' mode of operation for academics needs to be replaced by a drive towards technology readiness.

4. RESEARCH PROBLEM

Economies have attached significant importance to technology transfer as a catalyst of innovation [21]. The partnership between firms, research centres, and universities can lead to increased and improved innovativeness for successful technology transfer. The dilemma of technology development, technology readiness, and technology transfer can be overcome with a well-organised and effective TTO. The Amsterdam University, for example, has a distinctive approach with its TTO regarding innovation exchange (IXA) for partnering science for impact. Although the name (identity) of the office may not be crucial, it is evident that TTOs differ in function. Since the TTO is at the heart of the triple helix and UBC, a consistent TTO standard of best practice is needed with respect to the functions and hands-on learner management (how to go about things).

5. THE CASE STUDY METHOD

In search of a TTO standard of practice, the KU Leuven case study is presented for this purpose. Plowright [22] brought new approaches to research with respect to an integrated approach using narrative and numeric data. The case study is a good example of this mixed method approach. Authors such as Cooper and Schindler [23] and Saunders, Lewis and Thornhill [24] support case methodologies for a full contextual analysis with the combination of personal observation and facts about a phenomenon in order to understand events and their ramifications better. All in all, a case study comprises a detailed, in-depth study of a single subject to gain a better understanding of issues in a real-life setting. The primary purpose is to describe a phenomenon and to reveal how contemporary challenges are dealt with.

Truly vocational case studies inspire with lessons related to principles, concepts, events, and practical outcomes. The principles applied in the selection of the KU Leuven for the case study are (1) inspiring useful historic characteristics, (2) a contemporary problem (issue-bounded dilemma), (3) interesting facts and figures with vivid characters, (4) explanations of issues and concepts, (5) useful narrative data for readers/students, and (6) multidisciplinary scenarios.

6. THE KU LEUVEN CASE STUDY

[Note: Whereas most of the data used and shared in this report are available in the public domain, some of the sources and artefacts are only accessible (observable) through personal observation by appointment with reference to personal visits by the researcher.]

Similar to Kolb and Wagner's paper [14], this case study is based on a single university setting. As noted, the case study has several characteristics with respect to the KU Leuven's historic performance (world ranking) and benchmark status.

6.1. Innovation university

KU Leuven, founded in 1425, is Belgium's highest-ranked university. The institution's libraries are housed in a unique collection of buildings in 24 different locations, containing almost 4 million physical items. Each library occupies a focal position with collections that are among the most extensive and important in Europe. Besides its renowned library collection, which is currently an international symbol of cultural heritage, the institution is regarded as one of the most innovative universities in Europe, and is acknowledged as a founding member of the League of European Research Universities (LERU). It maintains a pioneering role in collaborative networks, providing leadership to scientific policy at the European level. KU Leuven offers a comprehensive research-driven education. With almost 60 000 students (18% outside Belgium, representing 140 countries) and 15 faculties, the university comprises 14 campuses in 10 cities of Flanders.

KU Leuven is an innovation hub with technical entrepreneurship and a tradition of an ecosystem consisting of investment capital, highly educated employees, technology platforms, research parks, and research networks. Almost 7 500 researchers are associated with the institution, which was placed first in the 2019 Reuters world ranking of most innovative universities. Besides 6 000 PhD researchers and a track record of 128 spin-off companies, it offers 50 Bachelor programmes, more than 130 Master's programmes, and 40 advanced Master's programmes.

The university's research output consistently ranks among Europe's best. It has acquired 415 projects, with funding from Horizon 2020 amounting to almost 230 million euros. In addition to receiving academic skills, students develop a vital capacity for critical thought, while state-of-the-art technology is integral to each qualification.

6.2. Personal observation

A recent (September 2022) visit to KU Leuven Research & Development (LRD) for the collection of narrative data formed part of several visits in Europe. The purpose of the research visit was to gain experiential knowledge with respect to academic power, the triple helix, and technology transfer. Essentially, personal observations confirmed that this TTO remains to be a useful benchmark.

Established in 1972 as one of the first TTOs in Europe, this office has become a benchmark, developing a tradition of collaborating with industry, securing and licensing intellectual property rights, and creating spin-off companies. LRD is the catalyst in building bridges between science and industry, transferring knowledge and technologies to the marketplace. Professor Desmet, vice rector of the Faculty of Arts, opines that "anyone who has worked with LRD for any length of time will realise that in fact there are no professors who do not benefit in some way from the services offered by LRD". KU Leuven has generated a most impressive spin-off portfolio, indisputably due to LRD. According to Professor Desmet, "the expansion of their LRD will be better able to anticipate the specific characteristics of each of our faculties, so that the exploitation potential of all the scientific disciplines can be tapped even more effectively". This vision for LRD predicts a possible technology transfer via a TTO stream per faculty in the future, since LRD is the backbone and driving force of the university and will take the practice of technology transfer to a next level.

Personal observation provided narrative data of evidence related to working culture, documents, models, images, and certificates. Examples of artefacts included high-tech entrepreneurship (supported by the Gemma Frisius Fund), the Reuters honorary title 'New Flemish Master in Science', IPTEC technology transfer award, software for digital dentistry, reduced tyre noise at Goodyear, refined cochlear implants, medication for the treatment of heart attacks and strokes, drug design such as the leading anti-HIV drug technology, the world's first patient-specific lower jaw, and rice with improved eating quality and reduced cooking time. Cosmolite is a best-selling lighter and stronger suitcase, and another success story after the university teamed up with Samsonite to adapt the material for the production of suitcases. Other famous impact stories include Tenofovir (an anti-HIV drug), the largest banana collection, thus safeguarding the future of this important foodstuff, and discovering the well-preserved archaeological site of Sagalassos.

7. PRIMARY FUNCTIONS OF THE TECHNOLOGY TRANSFER OFFICE

The core technology transfer functions of the TTO of LRD are: collaborating with industry, managing intellectual property, creating spin-off companies, providing access to incubation and seed financing, and stimulating a knowledge-driven regional development.

7.1. Collaborating with industry

Collaboration occurs from both directions when parties approach industry (or government) and when the external parties contact the university for several types of collaboration. Instead of performing the whole process themselves, companies, both small and medium enterprises (SMEs) and multinationals, often turn to the university to answer part of their R&D needs. When researchers collaborate with industry, LRD sets up well-balanced collaboration agreements which take into account the interests of all parties involved. In addition to carrying out services or research contracts commissioned by companies or other clients, researchers can also set up cooperative research projects together with companies or other organisations.

7.2. Managing intellectual property

When research outputs develop towards technology readiness for commercialisation, disclosing information (about methods, designs, and artefacts) becomes crucial. LRD's legal services help researchers to protect their intellectual property and devise appropriate strategies for transferring the intellectual property from the university to industry. LRD's IP officers guide researchers throughout the entire technology transfer process. Upon disclosure of an invention, IP officers assist researchers in assessing its patentability and market potential, applying for a patent, finding companies that have the resources to bring the technology to market, and licensing the patented technology.

7.3. Creating spin-off companies

With its entrepreneurial mindset, the university will always aim for the employability of students through several means. One way is to assist students in the creation of business opportunities based on their inventions and research outputs. Instead of licensing out an invention to an existing company, the intellectual property can also be the basis for setting up a new start-up business. LRD actively supports researchers who want to create a spin-off company. Typically, spin-off companies are new business ventures that exploit research results, know-how, and intellectual property developed within the university. LRD assists researchers during the start-up phase, and guides them through the process of translating a business idea into a business plan. Working closely together with LRD, researchers evaluate various markets for their potential and identify external business experts to support the team when needed.

7.4. Providing access to incubation and seed financing

The university always seeks solutions for real-life challenges such as health, nutrition, and energy. The LRD actively guides promising R&D projects that would not have had the chance to realise an industrial proof-of-concept or the production of a convincing prototype for the market. The LRD has created several specialised incubation instruments to meet the need for financing projects (e.g., the KU Leuven Patent Fund, the CD3 technology transfer platform, and the Gemma Frisius Fund). Whereas some universities use the triple helix engagement for a mere third stream of income with limited benefits for academia, academics at KU Leuven can benefit hugely from the services offered by the LRD. This is substantiated by Professor Delcour's declaration: "If it would not have been for LRD, I would not have stayed at KU Leuven."

7.5. Stimulating a knowledge-driven regional development

With respect to the macro perspective of technology transfer, the network relationships with the immediate located eco-system are maintained and improved. In close collaboration with the city of Leuven, the province of Vlaams-Brabant, and the Flemish and European authorities, LRD actively supports the development of a favourable climate for knowledge-driven entrepreneurship and innovation. In particular, LRD is an active partner in setting up networking initiatives such as Leuven.Inc, the network for high-tech entrepreneurship that was established in 1999, and technology clusters such as DSP Valley and LSEC, focusing on digital signal processing and IT security respectively. Together with Leuven.Inc, LRD organises specialised practice-based training sessions and creates awareness about innovation management and entrepreneurship. LRD is involved in planning, setting up, and managing incubators, science parks, and business centres that provide state-of-the-art lab and office space for innovative spin-off companies as well as international research-intensive companies.

The LRD also joined forces with the Vrije Universiteit Brussel (VUB) to develop a bio-incubator on the VUB campus. As a result, they set up Bio Incubator Brussels for start-up spin-offs. It develops academics from their first years of study in the immediate vicinity of research groups in the life sciences. According to Hugo Thienpont, vice rector of innovation and industrial relations at the VUB, "***[t]his dynamic self-supporting ecosystem of biotech start-ups will be able to make use of the research infrastructure, core facilities and pilot lines on our campus. In addition to logistics services, the bio-incubator will also offer programmes for encouraging, guiding and advising young entrepreneurs***".

8. ADVANCING THE IMPACT OF RESEARCH RESULTS

It is a common fact that too many IPs (such as doctoral theses in university libraries) remain of no value because they are not developed further. Technology transfer through the exploitation of research implies the development of academic power. In essence, the LRD coordinates and guides researchers in the administrative, financial, and legal aspects during the entire project life cycle. Professor Martens from the Centre for Surface Chemistry at KU Leuven is of the view that “LRD has always been able to find the right attitude and looked upon the exploitation of research as an opportunity rather than an imperative”.

Several well-known entrepreneurial universities, including the University of Twente (in The Netherlands), strive to improve research valorisation. Effective technology transfer requires a coordinated interplay between researchers, the experts of the TTO, and partners in government and industry. The LRD obtained 3 300 new agreements in 2018, with their spin-off companies having raised one billion euros of capital for a stronger regional high-tech economy. Successful technology transfer depends on high quality research, multidisciplinary teams, clear incentives, a favourable entrepreneurial climate, the ability to rely on networks, incubation instruments, and an integrated approach to technology transfer with respect to spin-off creation, intellectual property, and research collaboration.

LRD assists researchers in several ways, facilitates interactions between research groups, and stimulates the creation of structural multi- and transdisciplinary platforms such as Prometheus, which focuses on skeletal tissue engineering. LRD supports the entire technology transfer process, patent filing, and IP management. When an invention has been disclosed, IP officers assist researchers to assess the patentability (and market potential) of the invention and to find companies that are interested in bringing the technology to market. In addition, they facilitate the licensing of the patented technology.

The literature supports the exploitation of research results. Audretsch and Link [25] refer to innovation capital based on the development of academia, while Van Looy, Ranga, Callaert, Debackere and Zimmerman [26] propose a combined entrepreneurial and scientific performance in academia towards a compounded and reciprocal Matthew effect. Academic entrepreneurs use opportunities for research, engagement, and valorisation, making better academics [27].

Cunningham, Menter and O’Kane [28] refer to value creation with respect to research in a quadruple helix, while Steenkamp [29] refers to the quadruple helix of innovation based on academic power and triple helix ecosystems. The Triple Helix Association (THA) (www.triplehelixassociation.org) promotes the academic power of engagement as the new wave of the future in respect of entrepreneurial universities and an academic revolution. In this regard, Stanford University and the Massachusetts Institute of Technology (MIT) are the benchmarks, also advocating vocational PhDs.

Academics with quality research outputs can improve their technology readiness for commercialising solutions as intrapreneurs (for the university) and entrepreneurs by other means. Van der Sijde, Bossink, Van Hoorn, Van Gogh, Dekker, De Esch and Rozendal [30] report on such examples from the high-tech VU University, Amsterdam.

The KU Leuven LRD conducts training to develop academic power in collaboration with the Industrial Research Fund (IOF), the Leuven Arenberg Doctoral School, and other schools. The focus is on the exploitation of research output, technology readiness, and technology transfer. It also introduces doctoral and post-doctoral researchers of all disciplines into the three different routes of technology transfer, namely creating spin-off companies, patenting and licensing, and collaborating with industry (UBC). The programme is highly vocational, using practical case studies.

9. DIFFERENT MEANS OF TECHNOLOGY TRANSFER

As noted, ready technology is never easily or automatically transferred. This section of the KU Leuven case study describes a few domains and channels of technology transfer.

The university holds a holistic view of technology transfer over the entire spectrum of technologies. The four primary technology domains in the Leuven ecosystem are cleantech, nanotechnology, life sciences (health sciences, nutrition, interdisciplinary research, neuroelectronics and bioelectronics), and mechatronic smart systems. The different knowledge institutes, associations, and departments guarantee a continuous input of innovative ideas for technology transfer with direct cooperation with society as the most efficient way. Technology that is efficiently market-ready can be immediately transferred to an existing company, whether or not via tailored licensing.

9.1. Technology transfer through library technology

Images (artefacts) of the main university library of Leuven have become an international symbol of unique architecture, heritage, education, and research. In addition to comprising a unique collection of buildings, the unparalleled KU Leuven libraries house, for instance, the archive of the philosopher Husseri, and provide access to the work of humanists such as Vives, Thomas More, and Vesalius.

Knowledgeable library staff assist students and academics with digital literacy. Unique knowledge and technology transfer is enabled through, among other things, the RICH (reflecting imaging for cultural heritage) project and the KU Leuven fund for 'fair open access'. RICH is used to explore documents that were produced in mediaeval and early modern times. The imaging tool, named PLD (portable light dome), reveals the topography of mediaeval illuminations (stamps, inks, and seals), allowing them to be visualised and monitored in 3D. The KU Leuven fund for 'fair open access' promotes the development of new publishing models that are cost-effective, giving researchers and the entire scientific community control over the dissemination of their work, and enabling them to maintain the copyright to their own discoveries.

9.2. Technology transfer through university hospitals

The pursuit of outstanding medicine has led to the emergence of university hospitals. Patients come from all over Belgium to benefit from direct tech transfer with respect to health care. Physicians work in close physical proximity at the Health Sciences Campus, where researchers are able to test their findings in the hospital labs. Physicians thus benefit from substantiated scientific support when choosing the best treatment for their patients. Notably, survival rates at the Leuven Transplant Centre are among the highest in the world, and the university hospitals have achieved international recognition in the fields of oncology, hereditary diseases, and foetal surgery.

Tech transfer to KU Leuven's medical students is remarkable. Inspiring interaction is facilitated with respect to first-hand instruction, clinical experience of physicians (and other scientists), clinical care, and research in one location. In 2018, the university hospitals, with 1 686 physicians, conducted more than 15 million laboratory tests, 700 000 consultations, 400 000 radiology examinations, 58 000 surgical procedures, almost 30 000 kidney dialyses, and 300 transplants.

9.3. Technology transfer through the Pearl

A strong and dynamic triple helix cooperation has led to a very favourable entrepreneurial culture. The city of Leuven and the province of Vlaams-Brabant are known for high-tech business development and international (cross-border cooperation) high-tech entrepreneurship, referred to as the 'Leuven knowledge Pearl'. Cross-border collaboration includes the Eindhoven (Netherlands) and the Aachen (Germany) ecosystems. The Pearl ecosystem contains all of the necessary ingredients for tech transfer and innovation. Besides the university, it has other knowledge institutes and associations such as the VIB (Flemish Interuniversity Institute for Biotechnology) and IMEC, performing research on nanoelectronics, ICT, health care, and energy.

Technology transfer through most of the 135 KU Leuven and IMEC spin-off companies occurs within this ecosystem, and around 300 high-tech companies have set up operations in the Leuven region. The Pearl has significant investment capital available through funds such as Gemma Frisius Fund, Capital-E, Cappricorn, and the Quest for Growth funds. The Pearl is actively involved with the LRD's TTO office, maintaining the bridge between academia, science, and industry to transfer knowledge and technology to the marketplace.

Furthermore, The Pearl comprises state-of-the-art labs and office space with respect to incubators, science parks (similar to those in the Netherlands), and business centres. This includes the KU Leuven Innovation and Incubation Centre, the Leuven Bio-incubator, the Arenberg Science Park, and the Haasrode Science Park. The technology platforms in this ecosystem bring together like-minded researchers, consultants, and academic entrepreneurs. Ultimately this leads to the formation of network organisations such as the Vlaams-Brabant Innovation Centre, the Leuven Materials Research Centre, the Centre for Drug Design and Discovery, and many others.

9.4. Technology transfer platform for drug development

In the life sciences domain, the Centre for Drug Design and Discovery established a unique tech transfer platform with the investment support of the European Investment Fund. The centre aims to discover and develop drugs to a stage where pharmaceutical and biotech companies are interested in taking things further, with several possible strategies. Potential new medicines can also form the basis for spin-off companies.

9.5. Technology transfer platform for materials

Strategic Initiative Materials (SIM) was founded by primary material (e.g., glass) producers. It offers a platform for financing and coordinating joint ventures between universities and industry. SIM focuses on durable structural materials for energy and light, including tailored nanomaterials. This tech transfer process has led to several success stories, such as the development of a material with luminescent characteristics that increases the efficiency of solar panels.

9.6. Technology transfer for mechatronics and smart systems

The long-standing experience of KU Leuven is portrayed by their innovation outcomes since 1973 with mechanics, robotics, electronics, and mechatronics. This includes the PMA (production engineering, machine design, and automation) division as one of the first European labs, as well as LMS, one of the first spin-off companies of the university, which was acquired by Siemens in 2012. Another example of technology transfer success is Materialise, which has the world's largest rapid prototyping and manufacturing capacity in one single location. With regard to mechatronics, Krypton was one of the first spin-off companies, and accounts for 50% of the employment of Leuven spin-off companies. A direct tech transfer initiative is FMTC (Flanders Mechatronics Technology Centre), founded in 2003 to help with TTO functions, bridging the gap between academic research and industry. In addition, Imec's smart system research is concerned with energy-efficient heterogeneous integration technologies for innovative smart systems such as innovative visualisation, intelligent clothing, RFID labels, rollable displays, and lighting.

9.7. Technology transfer for cleantech

Water, air, and waste treatment and energy recovery have led to several spin-off companies, such as Waterleau and Bluways. The latter enables unprecedented reductions in harmful emissions and increases fuel efficiency. Smart grids have been developed, which are intelligent energy distribution networks that can avoid the overproduction of energy, bringing supply in line with demand. Specialised funding is available for 'cleantech' companies (e.g., Capricorn Venture Partners), as is expertise in sustainable manufacturing and sustainable structural materials. Imec holds a prominent global position in photovoltaic technologies, and, apart from solar energy, they focus on lightweight materials for windmills.

10. CONCLUSION

In search of a TTO standard of practice, this article addressed the contemporary problem of technology transfer (an issue-bounded dilemma). The technology transfer challenge is often preceded by the reality of 'innovation blindness', which can be addressed through effective TTOs and other strategies. The vocational case study of KU Leuven was described to address and encapsulate the phenomenon from a conceptual and pragmatic perspective. The conceptual perspectives included the philosophy of how technology makes contemporary society hang together, technology as a human construct, technology as an autonomous force determining society, and technology as a co-evolutionary process. Technology concepts were further explored with respect to academic power, technology readiness, and technology transfer perspectives.

The single case study of KU Leuven's LRD provides exemplary characteristics and inspirational facts about its historic performance (its world ranking) and its benchmark status. Personal observation of the LRD revealed evidence (models, images, and certificates) of several impressive artefacts. The case study explained how a TTO should operate across all scientific disciplines with respect to networking strategies, coaching, and assistance with all the stumbling blocks that could prevent successful technology transfer.

Exploration of the case was inspirational because it revealed the stimulation of a knowledge-driven region and the development of a triple-helix ecosystem. The LRD's know-how in advancing research results provides a huge opportunity for valorisation and technology readiness. It is also commendable to see how the research outputs become technology-ready for the Leuven ecosystem. Another important finding was the way in which the LRD transfers the technologies with different platforms for food, materials, drugs, mechatronics, and smart systems. The primary platforms used are the library, the university hospitals, the Pearl, and cleantech.

The enriching story of the KU Leuven's TTO is remarkable as a vocational benchmark. Although the detail of 'how to' is not fully discussed, it is recommended that this and other benchmarks be used to develop a TTO standard with respect to its functions and learner management. A training tool can be used as a canvas to assess and develop an institution's partnership approach, while other themes may include an engagement-readiness monitor, valorisation training, signposting technology readiness, possible options for spin-out companies, and IP disclosure. Besides KU Leuven, the university–industry innovation network (UIIN) provides such consultation.

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