The Importance of Information for Effective University–Firm Technology Transfer: The Case of ICAT–UNAM

Luis Roberto Vega-González
Universidad Nacional Autónoma de México

As part of their mission, faculties, centers, and research institutes of public universities in Mexico, develop technology products to a certain level of maturity. Normally, project development teams are devoted to building the hardware and software of the technology products but rarely deal with the commercial and technology management information required to advance the business plan for technology transfer. Socio-economic, organizational, and new project development information is normally prepared by personnel in the university's technology transfer office. Using a case study methodology, this article highlights the importance and the value of the information provided by technology studies undertaken throughout the different phases of a Research Development and Innovation (R&D+i) project, until the point of technology transfer negotiations. The presented study involves the case of a Mexican public R&D institute, the National Autonomous University of Mexico (UNAM).

Keywords: technical and commercial information reports, technology transfer, Mexican Public University

INTRODUCTION

This article focuses on technology developed in public universities of Mexico and possibly those in Latin America. In that context, rapid developments in technology drive the educational institutions; therefore, technology plays an important role in promoting effectiveness in both administrative and teaching–learning processes (Gülbahar, 2007).

A common fact is that universities in all countries make efforts to teach and also to develop high and emerging technologies; nevertheless, there are important differences in the way technology is developed between first world and developing countries. In first world countries, technology under research at universities is normally developed according a global institutional plan that is frequently based on technology roadmaps (TRMs) created and issued by manufacturers, government, research societies, and representatives of different economic sectors for national, industrial, and organizational levels (Arden, 2002; Amer & Daim, 2010). TRMs are strategy planning tools to integrate business and technology, and are sometimes used in combination with other planning techniques such as dynamic simulation and scenario planning (Geum, Lee, & Park, 2014).

Petrick and Echols (2004) and Lee and Park (2005), as quoted by Geum and Park (2013), indicate that for the past decade, technology roadmaps have captured diverse information on technology evolution and new product development. They explain that a technology roadmap is an aid to navigation. It is further defined as the views of a group of stakeholders who wish to achieve a desired objective.

In a number of cases, technology roadmaps are the basis and foundation of government policies for strategic sectors such as energy, computer and electronic product manufacturing, new materials, genomic health products, and so on (Lee, Mogi, & Kim, 2009; Lu & Weng, 2018).

Kostoff, Boylan, and Simons (2004) discuss the importance of looking for disruptive technology roadmaps, arguing that disruptive technologies create growth in the industries they penetrate or create entirely new industries through the introduction of products and services that are dramatically cheaper, better, and more convenient. Disruptive technologies can evolve from the confluence of seemingly diverse technologies or can be a result of an entirely new technological investigation.

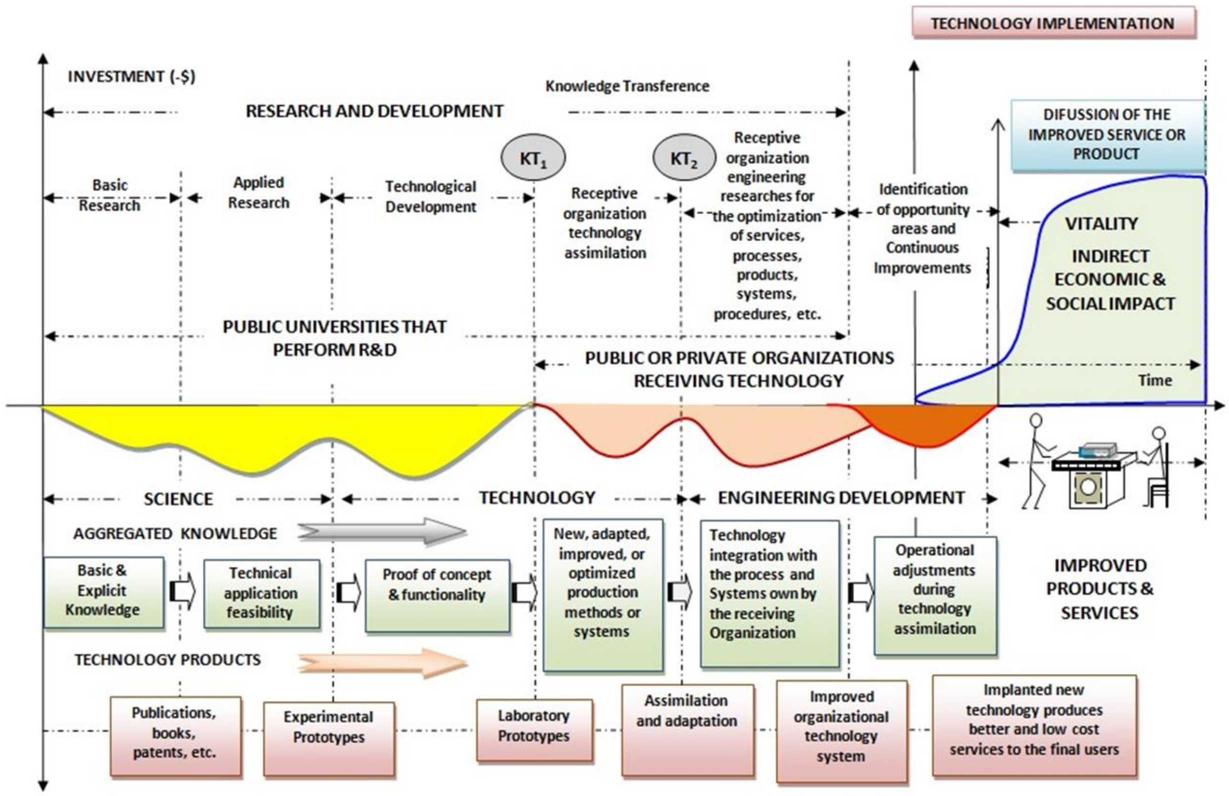
On the other hand, there is a frank absence of planning at public universities of developing countries and, therefore, the ways in which technology is developed are diverse and deeply inconsistent. Letaba and Pretorius (2021) mention that in the case of developing countries, the dynamics of innovation ecosystems differ from those in developed countries and the need for sociotechnical transition projects is often quite high. Therefore, a framework for technology roadmapping large projects could bring systemic sociotechnical transitions.

Naturally, the first problems in following a long-term organizational technology development plan are the scarce economic resources and the austerity. As a result, it is difficult to pursue the development of high-tech. Gülbahar (op. cit.) mentions that since the advent of technologies for teaching and learning, schools in Turkey have been allocating a considerable proportion of their funds for the procurement of high-tech; however, up to now there has been little success.

As mentioned previously, this article addresses technology development in the universities of developing countries, specifically in Mexico where there is an inability to look beyond short-term profitability and the risk/return trade-off of longer term projects. Therefore, nearly always, the first source of technology prototypes is developed as part of the human resources formation curricular and capacitation courses. Hence, some technology seeds begin with undergraduate, graduate, and post graduate thesis projects. The resulting technology is embodied in bench or concept testing prototypes, presented as the first stages in the project development model of **Figure 1**. When technology is promising, university faculties, centers, and institutes frequently continue performing subsequent stages for technology improvement.

Sometimes, technological development contracts are signed with companies or public or private organizations, where the counterpart will finance the development and improvement of technology prototypes as they pass from concept to laboratory prototypes and, in some cases, to precompetitive products. As can be seen in Figure 1, nearly always, technology is developed in several stages or phases.

FIGURE 1
LINEAR MODEL OF TECHNOLOGY DEVELOPMENT PHASES AT UNIVERSITIES



Vega 2015

Let us suppose that the student project is finished and he or she obtains their graduate or undergraduate title and leaves the university to join the world of work. Also suppose there are no more students to continue improving technology without pay but who also to graduate. What does it require to continue with the development and improvement of the prototypes? Of course, the first concern of the development team is that there are enough financial resources to continue with the design works.

In the case of contracted projects, economic resources will come from the client or counterpart. In the case of technologies not contracted by a firm, development depends on the institution's interest; in such cases, the required financial resources will come from the institutional budget. Of course, immediately there comes a decision-making problem: which technology is promising enough to invest normally scarce financial resources? To answer this question, the leaders of the work team need to have specialized and specific information.

Technology products also can have other origins; for example, sometimes they are the result of the institution's research projects. Once those projects are finished, the authorities must also decide whether to continue improving the technology in order to seek its transfer to another institution or to a firm for its manufacture and commercialization.

In any case, it is imperative to have good and timely information. This is why along the technology development project stages it is suggested to develop many studies related to the technology. The information and data required could come from studies as foresight, technology intelligence systems, monitoring, market profile, state-of-the-art, technical and commercial feasibility, patentability, intellectual property strategy, technology evaluation, valuation, business plan, project industrial escalation feasibility and profitability, sales forecast, a comprehensive market study, and time to market, among many others.

The good news is that all of a project's technical, socio-economic, and financial studies reports carried out within the first three stages (known as the Precompetitive Technology Development Phases) can be used to form a technology transfer file that could later grow to become a "project book," which will be the main information source that the technology transfer team will have and use when the moment of negotiations arrives.

At the center of Figure 1, it can be seen that when the development process has been well directed and has been guided by information from market profiles and technological roadmaps, a clear and authentic interest could be generated in the interested firm and, in some cases, it is possible to sign an escalation agreement to achieve low-volume production of the technology that is still in the phase of laboratory prototype. After that, the process of technology transfer negotiations begins, which possibly culminates with the signing of the Licensing and Technology Transfer Agreement.

In the last period of the development and prior to market launch, the technology prototype belongs to the licensee and the technology product ceases to be a semi-industrial prototype because the new industrial product is developed and scaled by the company. In this moment, new financial studies, such as costs, product price and consumer preferences, must be performed in order to have market success.

The general objective of this work is to show the importance of performing technical, socio-economic, and financial studies during the different stages of technology development. We also pursue two specific objectives: (1) to assist the development team, authorities, and technology management personnel to adjust and redirect projects as required according to market studies, intelligence, and technological road maps, and (2) to prepare a file or information book that will help the management team to carry out the negotiations when the technology transfer time arrives. The research method used will be the case study of the implementation of the Technological Studies Unit of the Institute of Applied Sciences and Technology (ICAT) of the National Autonomous University of Mexico (UNAM).

LITERATURE REVIEW (THEORETICAL FRAMEWORK)

Practical Issues for Technology Transfer

Who performs technology transfer practical activities? Volberda, Oshri, and Mom (2012) mention that in recent years we have witnessed the emergence of a new profession, often referred to as the "technology transfer (TT) manager." TT managers apply various skills to accomplish technology transfer such as legal competencies, marketing and negotiation competencies, team work competencies, innovation competencies, and knowledge management competencies.

According to Rahal and Rabelo (2006), those are the central competencies required for the commercialization of an invention.

Technology management practitioner managers also use other practical activities when they handle R&D projects such as project formulation, supervision of the project stages, finance and auditory supervision, negotiations with the authorities and the development academic groups, negotiations with technical, legal and accounting groups, follow-up of deliverables in a timely manner, conduct acts and agreements for project closure as well as intellectual property strategy, among many others. Moreover, Nguyen and Aoyama (2015) point out that there are five management practice constructs that the technology manager and their team may use to perform their function effectively: management commitment, quality practice, team-based work, training, and sharing and understanding.

Particularly, technology transfer grants exploitation rights from the technology developer to the part or firm that will exploit them and converts technology prototypes into new commercial products for market, thus achieving an innovation.

On the other hand, there are a number of elements faced in the practice of successful technology and knowledge transfer. Nguyen and Aoyama (op. cit.) find that culture is a particularly significant factor in the expansion of manufacturing activities from developed to developing countries through technology transfer channels. The issue of cultural difference is of crucial importance to the efficient achievement of cross-cultural technology transfer and is a major challenge for managers undertaking international technology transfer projects. Of course, there are negative and positive impacts of cultural difference on efficient technology transfer. The adverse impact of cultural difference plays an important role in eliminating the potential for successful technology and knowledge transfer and causing the failure of the international technology transfer process (Lucas, 2006, quoted by Nguyen & Aoyama, op. cit.). Nevertheless, the problem of cultural differences can even occur due to the type of activity that is developed; that is, technology transfer is seen and conceptualized differently by a university academic group than an industrial entrepreneur or a politician.

Gallini and Wright (1990) propose that in the market for the rights to adopt an innovation, the supplier of these rights is challenged with a principal–agent problem: the design of a licensing contract that maximizes profits given the potential for opportunism by both parties in the contract. It is a maximization problem similar to those handled by operations research.

The main salient features commonly observed in licensing contracts are the sales royalties, the rent sharing between the licensor and licensee, and exclusivity versus non exclusivity.

Thus, Gallini and Wright (op. cit.) also stress the fact that the licensing contract terms can be explained as responses to two specific facts for the exchange negotiations: (a) the *superiority of a licensor's information* on the value of the innovation and, (b) the ability of licensees to "invent around" the transferred innovation.

In practice, it is observed that in negotiations carried out *under asymmetric information*, a licensee will be reluctant to undertake specific investment in the technology without some assurance of its profitability (Teece, 1987, quoted by Gallini and Wright, op cit.).

This happens in any country; however there is a danger of not achieving the licensing agreement if the less informed party, the licensee, is aware of the licensor's incentive to convey misinformation. Furthermore, a common complaint among manufacturing firms is that "there is a tendency for the licensor to be overly optimistic about the commercial significance of a licensed innovation" (Lovell, 1968, quoted by Gallini & Wright, p.148).

Therefore, it is very important to have good and adequate information that can be shared openly between the parties without hiding anything to achieve a good technology transfer agreement. We stress the fact that at the moment of technology transfer, the negotiation needs to be fair and a win–win contract must be achieved.

Technology Transfer in Developed Countries

Nguyen and Aoyama (op. cit., p. 927) propose that between developed and undeveloped countries, the term "technology transfer" refers to the complex process of transferring technological knowledge, information, and know-how across organizational borders from developed to less technologically developed countries through which the final technology recipients acquire, absorb, and apply new knowledge to create the same production and management execution conditions as the originating economic entity.

Carlsson and Fridh (2002) state that following the Bayh–Dole Act of 1980, many U.S. universities set up offices of technology transfer (OTT) in order to facilitate the commercialization of research results. Technology transfer from universities to the commercial sector needs to be understood in its broader context. It is not simply a matter of maximizing income for the universities even though in a few cases quite substantial income is generated. It is rather a matter of finding the proper balance between the basic functions of teaching and research within the universities on the one hand and providing a service to the wider community on the other. The primary purpose of a university's technology transfer program is to assist its researchers in disseminating research results for the public good.

There are several stages in the technology transfer process, each associated with its own outcome: invention disclosure, patent application, patent issued, license sold, license income, and/or business start-up. As a rule, only half of the invention disclosures result in patent applications; half of the applications result in patents; one-third of patents are licensed, and only a handful (10–20%) of licenses yield substantial income. It practically means that probably among all inventions, just one or two could produce incomes to the university and to the inventors.

Lockett, Wright, and Franklin (2003) propose that universities may seek to transfer technology from the public to the private sector, thereby capturing the benefits of commercialization through a number of different mechanisms. One of them is the creation of technology-based spin-out companies. The more successful universities possess a greater expertise and networks that may be important in fostering spin-out companies.

The commercialization of university-based technology has become a prominent issue in the policy arena in both the U.S. and the U.K. The spinning-out of inventions into separate companies represents a potentially important but as yet under-exploited option. In the U.S., the transfer of technology from the public to the private sector is increasingly regarded as playing a significant role in new business starts, growth of existing businesses, and new job creation (Siegel et al., 1999; cited by Lockett, Wright, & Franklin, op. cit.).

THE VALUE OF INFORMATION TO RESPOND TO DETERMINANTS OF TECHNOLOGY LICENSING

The details of the technology transfer practice show the value of having adequate information when the technology transfer negotiations begin, a period that is called the "technology transfer time." Technology transfer is usually initiated when there is asymmetric information between the parts; situations when there is total symmetric information between the parts are rare and hard to find (Gallini & Wright, op. cit.). Why? Because appropriate validated information provides some negotiation advantage to the part that relies on it. Therefore, arriving at a fair win–win negotiation requires not only good personal negotiating skills but also having appropriate product, market, and financial information.

Gallini and Wright (op. cit., p. 147) mention that licensing contracts for newly patented innovations are observed to vary along several dimensions, including the form and size of the payment to the inventor. They point out that *"the transfer of patented innovations through licensing can be as complex as the inventive process itself"* and that there are two main problems in technology exchange: (a) the superiority of a licensor's pre-contractual information about the economic value of the innovation and (b) the fact that sharing this information with the licensee may facilitate imitation.

In their literature review, Rahal and Rabelo (2006) identify 43 determinants crucial to the successful licensing and commercialization of university technologies. These determinants are classified in **Table 1**.

TABLE 1
UNIVERSITY TECHNOLOGY COMMERCIALIZATION DETERMINANTS

Institutional	**Inventor-related**	**Market- & Commercialization-related**	**Technology-related**	**Intellectual property-related**
1. Technology transfer office	1. Inventor involvement and	1. Nature and sophistication of the technology (high or low)	1. Nature and sophistication of the technology (high or low)	1. Technology's literature search is
2. Universities licensing policies determinants	2. Inventor being recognized as technology leader	2. Absence of a dominant competitor in the technological field	2. Scope of the technology (future uses)	2. Patent search is completed and is clear and clean
3. Institutional prestige influence determinants	3. Invertor credibility in the field	3. Technology has a large definable potential market	3. Technology's quantifiable benefit and advantages as perceived by the user when compared to current competing products	3. Confidentiality of the technology (no oral or written disclosures)
	4. Inventor has realistic expectations about his or her technology	4. Technology's market growth anticipation	4. Technology's significant benefits and advantages as identified and perceived by the user	4. Technology has no prior claims
	5. Incentives to inventor by the licensor	5. Technology's expected market trend	5. Technology development time to market	5. Strength of intellectual property
		6. Time for the technology to reach the target market penetration	6. Technology's sustainable competitive advantages and superiority as perceived by the user	6. Exclusivity of intellectual property
		7. Market accessibility for the technology (no dominant technology)	7. Technology uniqueness and superiority	
		8. Technology's competitive pricing	8. Stage of development of technology	

		9. Technology has a reasonable probability of market success	9. Barriers to entry	
		10. Technology being first to market (early mover advantage)	10. Newness and the non-obviousness in the technology	
		11. R&D necessary for the technology to reach the product development stage	11. Availability of a functioning prototype	
		12. Technology's expected payoff period	12. Technical feasibility (such as technical problems are solvable)	
		13. Technology's expected positive return on investment within a specified period	13. Technology's degree of dependability on other necessary technologies	
		14. Technology's financial risk	14. Technology's degree of compatibility to other necessary technologies	
			15. Technology's identifiable and quantifiable technological risks and weaknesses	

RESEARCH METHOD: THE CASE STUDY

The research method applied in this work was the case study. This method allows the inductive analysis of qualitative data recovered from the case description (Martínez, 2006); however, this type of research presents some uncertainty because quantitative methods are not applied. The scientific knowledge acquired using case studies requires working with analogies, inferences, presuppositions, and conclusions in order to logically structure both the definition and the foundation of the problem (Aguilera, 2011). This implies having a specific conception of reality.

From the perspective of scientific knowledge, the problems that are studied and analyzed with case studies are human elaborations and social constructions, elaborated based on certain particular conceptions of reality. For Yin (2003), the case study method is a valuable research tool whose greatest strength lies in the fact that it measures and records the behavior of the people involved in the phenomenon studied, whereas quantitative methods only focus on numerical information obtained through questionnaire surveys.

A case study consists of detailed investigation of one or more organizations, or groups within organizations, with a view to providing an analysis of the context and processes involved in the phenomenon under study (Meyer, 2001).

An important advantage of case study research is the opportunity for a holistic view of the process: “The detailed observations entailed in the case study method enable us to study many different aspects, examine them in relation to each other, [and] view the process within its total environment” (Gummesson, 1988, p. 76)

Tellis (1997) considers that a case study can be seen to satisfy the three tenets of the qualitative method: describing, understanding, and explaining. It is one of the most powerful methods used by researchers to realize both practical and theoretical aims, and is a research method commonly used in the management of technology investigations.

THE ICAT CASE: THE CREATION OF A TECHNOLOGICAL STUDIES UNIT

The Institute of Applied Sciences and Technology (ICAT) is part of the Scientific Research Subsystem of the National Autonomous University of Mexico (UNAM). The actual ICAT was created in 1971 as the Instruments Center of the Scientific Subsystem of the National Autonomous University of Mexico. In 2002, it was transformed to the Applied Sciences and Technological Development Center (CCADET) and later upgraded to the actual research institute in March 2018.

One of the main objectives of ICAT has been to establish links with external organizations from different economic and social sectors and develop technological solutions responding to their requests, seeking to apply the knowledge generated over the years in academic groups to help solve problems relevant to the country.

ICAT currently has approximately 120 research fellows and academic technicians and about 200 people in the administrative and support areas. It is a multidisciplinary organization that works in various fields of knowledge, developing projects for the following application areas: health, science and technology education, environment, and energy.

The ICAT had its origins as an Instruments Center (CI) in 1971. At that time, there was an intuitive idea among academic staff and their authorities about the need to carry out linkage actions with other public organizations seeking to support them in solving their scientific and technological problems. This idea stopped being intuitive and soon became part of the Internal Regulations of the institution.

In its first decade of operation, the actions of the projects carried out by the academic staff were directed to lab equipment maintenance support of other university entities. A second area of work was in conducting feasibility studies for the industrial production of scientific and technological equipment and instruments developed by the CI staff. Within the objectives of the creation of the Center, it was also tacitly stated that the entity should promote the filing of patents to protect the industrial property of UNAM.

From 1971 to 1999, linkage actions were carried out directly by the personnel responsible of the projects and by the authorities of the Center, who signed the collaboration agreements because there was no office in charge of the execution and coordination of these activities. The ICAT's Office for linking, project development agreements, intellectual property strategy, and technology transfer was created in 1999. Since 2018, it has been the Secretariat for Technological Linking and Management.

The ICAT's Technology Transfer Orientation

Today, almost fifty years later, the institute's objectives have been expanded to carry out link and contact actions with other sectors of society and to transfer the technology developed at ICAT to the productive and academic sectors with the intention of contributing to innovation national technology and with the improvement of science, technology, and education at the national level.

In the U.S., on December 12, 1980, the Bayh–Dole Act (or Patent and Trademark Law Amendments Act) was signed, whose main objective was to modify the terms of ownership of inventions obtained with governmental funding by universities and organizations in that country (Franzoni, 2007). Prior to this agreement, the patrimonial intellectual property of the inventions resulting from a project in which the universities or other contractors had received government funding to carry out a project belonged to the government. The fundamental change was that the government, based on the public and social interest, authorized that the intellectual property rights be granted to the university or the contractor of the project.

According to the Organization for Economic Cooperation and Development (OECD, 2006) of the United Nations (UN), at the beginning of this century, most Latin American countries enacted laws based on the Bayh–Dole Act, granting universities the intellectual property rights of inventions obtained as a result of their projects sponsored with public funds from the government.

The UNAM joined this current of promulgation of international rights and demanded from the Mexican Federal Government, through the National Council of Science and Technology (CONACYT), the patrimonial property rights of the technologies developed by the academics of its different entities. The UNAM also reserved the property of the technology and inventions developed as part of its substantive work of human resources formation including research. In all those cases, economic resources did also come from governmental budgetary funds. In other words, it is understood that the salaries of the personnel and the infrastructure of its different entities were covered in their highest percentage with the public budget.

Recently passed is the Regulation of Extraordinary Income issued by the UNAM´s General Abogacy, known as "General Lawyer Guidelines on Transfer of Technology and Knowledge at the National Autonomous University of Mexico" (Gaceta UNAM, 2019).

According to current regulations, these resources can be used by the university to promote its R&D activities by acquiring new equipment and infrastructure, and even giving the opportunity to make the payment of extraordinary additional incomes to academic personnel who have collaborated in the development of the technology. During last two decades, an important number of R&D projects were developed and some technology inventions obtained (www.icat.unam.mx); most of them were delivered to public and private institutions that requested and financed their development for their own use and just a small proportion was licensed and transferred. **Table 2** shows the list of technology transfers made through licensing agreements signed with public and private counterparts during this period.

A New Institute With New Challenges

Nevertheless, when the Center changed to an institute in 2018, its new objectives indicate the importance that the knowledge and technologies obtained must have greater social and economic impacts and must help solve problems relevant to the country. In other words, technology transfer must be intensified.

In this sense, the main objective of the Institute was to have an increase of 50% of the transfer of technologies with social and/or economic impact during a period of between five to seven years. This would require transferring four to five high-impact technologies in that period of time, substantially improving the results previously achieved. That means an average of one invention transferred to society each year. To achieve this, ICAT's academic research and development groups must generate more technologies and applications, mainly in response to the demand from external organizations.

A *sine qua non* condition for achieving more technology transfers and licensing is to have adequate and high-quality socio-economic and financial information. Doing so requires conducting different studies for each of the technologies developed or that are under development.

It seems that it is not a good idea to carry out the studies until there comes the time of technology transfer negotiations because situations like saturation and lack of personnel and time to carry them out could arise. For this reason, it is more pertinent to initiate corresponding studies from the beginning of the projects and to improve and expand them as the technological prototypes are created, improved, grown, and transformed.

In fact, technology transfer and licensing requires that the staff of the technology transfer office integrate technology packages. They also must opportunely draft and request the intellectual property rights that are most appropriate for the case and propose the business strategy to achieve a technology transfer at least every two years. It is thought that adopting this strategy will allow the ICAT to reach the objectives of its development plan, which is to increase the transfer of technology to both the public and private sectors and mainly to the companies that will diffuse the technology licensed to the market.

To achieve the above, the actions that the ICAT's office of linking and transfer of technology (SVyGT, from the Spanish) are implementing are the following:

- Consolidate the Intellectual Property Unit in order to increase the number of utility patents and utility models[1] applications for the inventions obtained by academics of the institute at the rate of at least one or two protecting instruments per year. For this, it is necessary to develop patentability studies and state-of-the-art studies for the inventions that are more promising in terms of commercial and/or social impact. This Unit shall keep the statistics and audit studies of the registered intellectual property.
- During 2021–2022, develop a new Information Unit to carry out diagnostic studies of the intellectual, human, and organizational capital of unregistered intangible assets embedded in technological packages. It will also be in charge of the valuation of the institute's technological prototypes and its intangibles such as its intellectual property titles. They must also develop market profiles for each of them.
- In the medium term, that is, by 2025, develop a Business Unit for the promotion and transfer of technologies, whose objective will be the detection of business opportunities, participation in fairs and events related to the sale of technology, negotiations and transfer contracts development.
- In the long run, that is, by 2028, develop a new integration engineering group to transform CCADET laboratory-level prototypes to a pre-industrial scale, manufacture of finished robust prototypes, performance of quality tests and quality certifications, and safety and destructive tests. In addition, this group must obtain compliance with standards such as NOM and/or UL records as appropriate and sanitary approvals as required by the case.

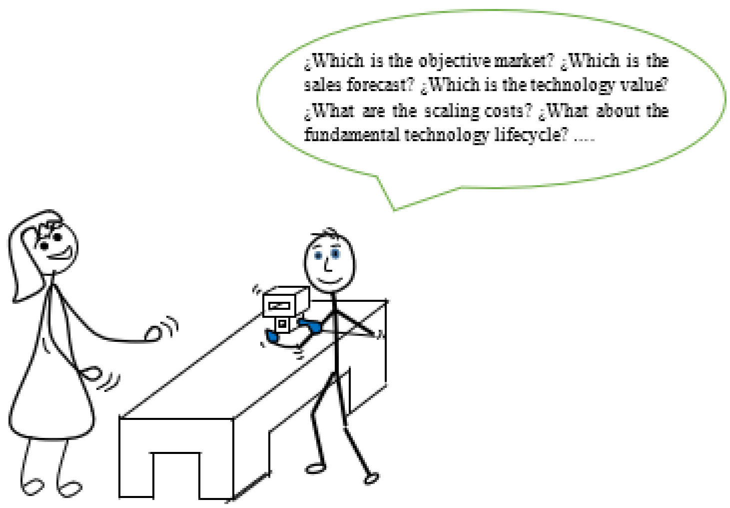
TABLE 2
LIST OF REGISTERED HISTORICAL LICENSES AND TECHNOLOGY TRANSFERS AGREEMENTS FROM ICAT

Year	Academic Research Group	Technology	Counterpart	Payment terms
1999	Cognición y Didáctica de las	Laboratories for teaching science at the	Fernández Editores SA de CV	Royalties 5%
1999	Cognición y Didáctica de las Ciencias	Laboratory of Optics, and other equipment as Air Table, Induction Coil, Electrostatic Generator, Electroscope, Magnetic Field Plotter.	Harry Mazal SA de CV (Firm)	Royalties 5%
2006-1	Cognición y Didáctica de las	Laboratory of Natural Sciences, EDUCIENCI,	Fernández Editores SA de CV	Royalties 8%
2006-2	Cognición y Didáctica de las	Laboratory of Light and Optics, EDUCIENCI,	Fernández Editores SA de CV	Royalties 8%
2006-3	Cognición y Didáctica de las	Laboratory of Mechanics, EDUCIENCI,	Fernández Editores SA de CV	Royalties 8%
2006-4	Cognición y Didáctica de las	Laboratory of sound, EDUCIENCI, Elementary	Fernández Editores SA de CV	Royalties 8%
2006-5	Cognición y Didáctica de las Ciencias	Laboratory of modular mechanics, EDUCIENCI, Elementary Schools	Fernández Editores SA de CV	Royalties 8%
2006-6	Cognición y Didáctica de las Ciencias	Laboratory of Electricity and Magnetism, EDUCIENCI, Elementary Schools	Fernández Editores SA de CV (Firm)	Royalties 8%
2010	Sistemas Inteligentes	"Technology for the adoption of expert systems for the prediction and control of pests"	Fundación Produce Michoacán (NGO)	$380,000.00 MN (Fee)
2010	Cognición y Didáctica de las	"Laboratory de Sciences for High Schools	FOLISERVIS, SA de CV	Royalties 8%
2010	Cognición y Didáctica de las Ciencias	School Laboratory of Automated Sensors (LESA), User Manual and computer system	Educación y Tecnología para la Ciencia S de R. L. de C. V.	4% Royalties
2012	Cognición y Didáctica de las	"Laboratory of Light and Optics for Kinder	CLEZAGA SYSTEMS S. DE	8% Royalties
2016	Laboratorio Nacional de Manufactura Aditiva y	Manufacturing process of PMMA skull maxillofacial implants, using additive	Partes e Implantes Avanzados S de RL de CV (Firm)	Front payment plus 3.5%
2018	Grupo de Dispositivos Biomédicos	A *HepaScan* System License for the exclusive use of the Pathology Service, and a license for	Hospital General de México "Eduardo Liceaga" (Public	Free
2019	Laboratorio Nacional de Manufactura Aditiva y	Manufacturing process of PMMA skull maxillofacial implants, using additive	PAPIME 2019, Faculty of Philosophy, F. Faculty of	Free
2020	Espacios y Sistemas Interactivos para la	Teaching model and collaborative technologies: desk and collaborative wall of the Classroom of	College of sciences and humanities Vallejo,	Free
2021	Espacios y Sistemas Interactivos para la	Teaching model and collaborative technologies: desk and collaborative wall of the Classroom of	UNAM High Schools N° 8, 6 y 2, Faculty of Arts and	Free

The Questions at the Time of Technology Transfer

Transferring technology from a university to a firm is a complex process. Being mainly a negotiation process, it requires making a good impression from the start. The time of technology transfer negotiations occurs when the ICAT's inventors and/or the technology transfer personnel gets in front to the interested firm representative and a number of questions appear.

FIGURE 2
BASIC QUESTIONS FOR TECHNOLOGY TRANSFER NEGOTIATION



The first contact sometimes occurs in a technology fair or at a negotiation desk. Sometimes, a representative of the firm visits the university installations. As can be seen in **Figure 2**, whatever the contact method, it is at this moment when a number of questions arise.

Naturally, to answer these questions, specific, current, and timely information is required. Let us take a closer look at the process. The first contact can be between the entrepreneur and the academic developer. The TT office representative should almost always participate. The answer to the questions must be firm and concrete. Achieving this requires that the development group and/or the technology manager have specific technical, market, economic/financial information related to the technological prototype and also about intellectual protection, and at least an idea of the value of the technology. Using all this, the university group could even propose a business plan.

The expected effect is that when the representatives of the institution respond, deliver, and exchange real and reliable verbal information, the communication exercise will have a confidence-building effect on the counterpart. If the process goes on, then a confidentiality agreement must be signed to allow printed information exchange that will permit fair technology transfer negotiations under conditions of symmetrical information and will prevent negotiations from being abandoned.

Under this condition, the representative of the firm can in principle know if the technology is within their reach and determine if they can, on the one hand, defray the costs, including the cost of technology transfer, as well as make the required investments in infrastructure, human capital, materials, logistics, and marketing required to scale the prototype to a precompetitive technological product, and to later carry out the development project of a new competitive or industrial product, which must be launched on the market to achieve their exploitation.

This step is essential to maintain and increase interest on the entrepreneur's part so that the negotiation meetings can continue until an agreement is reached on the terms of payment of the technology and a fair licensing and technology transfer agreement is signed.

RESULTS

The solution proposed at the ICAT to have good and adequate information for the technology transfer negotiations was the implementation in 2020 of an Information Unit (IU) attached to the Secretariat for Technological Linkage and Management. Due to the problems of the Covid-19 pandemic, this unit has not been able to fully enter into operation at the time this manuscript was prepared in July 2021. Within its first tasks, the UI must perform a diagnosis to identify those technologies with the highest level of technological maturity (Technology Readiness Level, TRL) that each of the academic groups of the institute has developed. From these technologies it will be necessary to select those in which there is already an interest from a public or private counterpart. Next, the personnel responsible for the UI must collect data and technical information and prepare technological roadmaps as well as carry out specific required studies according to the different stages of development of the different technologies.

The following seven stages describe the minimum catalog of studies proposed and required for the different stages of development of the different technological prototypes of the institute.

Stage 1: Definition of the project idea within the institutional research lines

Foresight
Technological surveillance
Technology roadmaps
Basic technology intelligence system

Stage 2: From project idea to proof-of-concept prototype

Market monitoring for similar technological products: technology need, potential users, competitors
Technical feasibility
State-of-the-art: identification of existing patents, utility models, of similar technologies
Technology domains required for successful technology concept development

Stage 3: From proof-of-concept to laboratory prototype

Market profile
Intellectual property strategy
Intermediate technology intelligence system

Stage 4: From laboratory prototype to precompetitive technology

Commercial feasibility
Intellectual property strategy
Drafting and application for patents, utility models, and copyrights
Technology valuation
Technology intelligence system improved
Technology readiness level (TRL) measurement
Testing Report

TECHNOLOGY TRANSFER TIME BETWEEN THE UNIVERSITY AND THE FIRM

Stage 5: From precompetitive technology to industrial prototype

Final product performance
Project costs evaluation

Industrial production feasibility
Industrial scaling study and product design
Low-scale production testing
Market preferences study
Sales forecast
Business plan

TECHNOLOGY TRANSFER WITHIN THE DEPARTMENTS OF (NPD)-(PRODUCTION) OF THE FIRM

Stage 6: From industrial prototype to commercial new product

Market study
Price study
Product technology roadmaps
Production line manuals: infrastructure, supply chains, operators, power consumption
Regulatory compliance
Quality norms (ISO, NOM, EPA)
Good manufacturing practices (GMP)
Security assurance and compliance standards (UL)
Environmental norms compliance

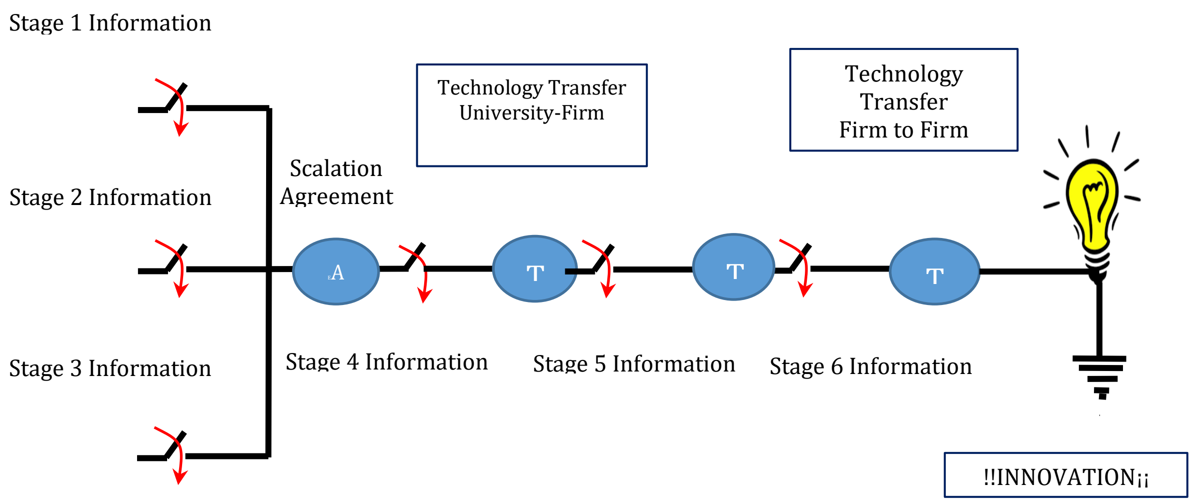
TECHNOLOGY TRANSFER FROM THE FIRM (PRODUCTION) TO THE USER (SALES)

Stage 7: Launch to market and technology diffusion

Market acceptance
Improvements and claims of the new product
Price study adjustment
Feedback technical and commercial information

The information obtained for each project stage will allow the university development team to take the required technical and economic decisions to advance to the next process stage. Technology transfer time is essential prior to innovation as can be seen in **Figure 3**. The information circuit innovation output establishes symmetric technology information to be used for the TT negotiation table.

FIGURE 3
PERMISSIVE INFORMATION CONTROLS FOR TECHNOLOGY TRANSFER AND INNOVATION



In **Figure 4,** we suggest the general information requirements along the development path of a Research Development and Innovation (R&D+i) project.

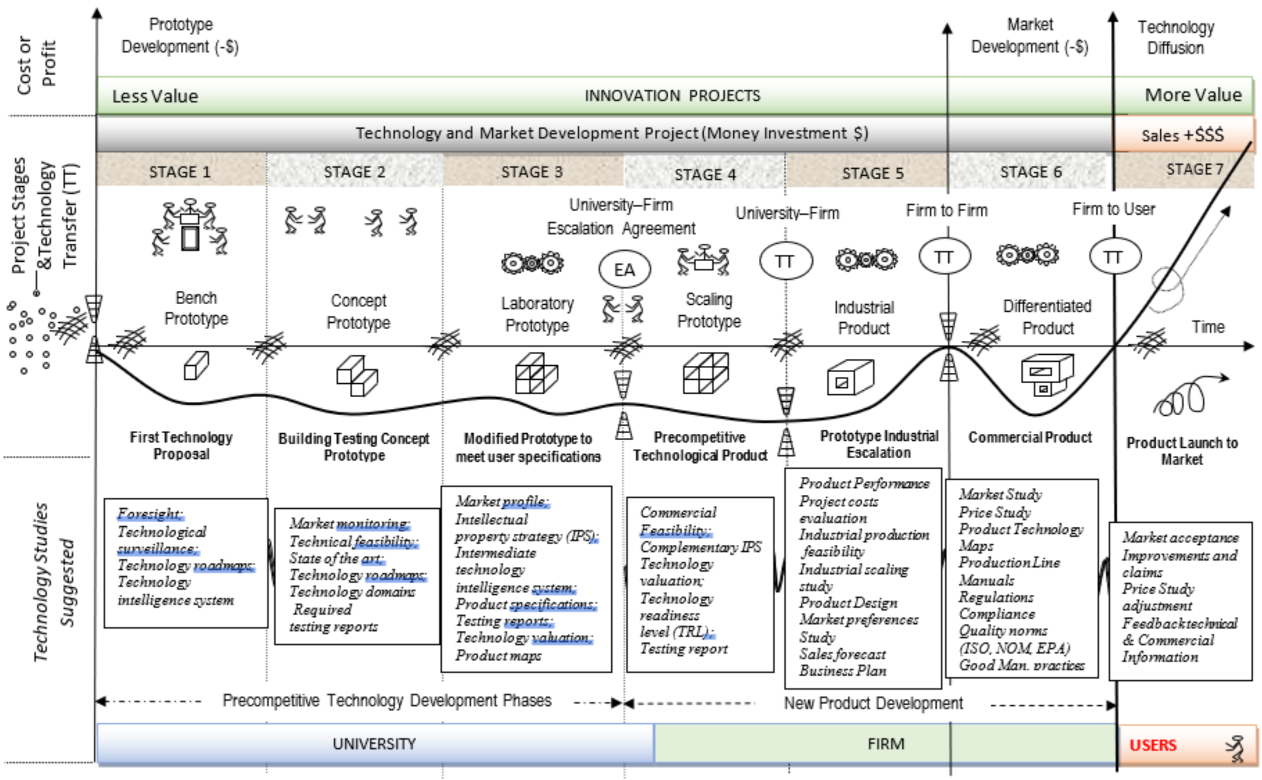
DISCUSSION

Information provides a sense of certainty to whoever has it. According to Martin (2012), many firms say that information is their most valuable asset yet even if advance information cannot influence an upcoming event, people (and animals) prefer to know ahead of time what the outcome could be (Niv & Chan, 2011). Therefore, information has intrinsic value.

Alfonso et al. (2016) point out that the main concepts of value of information (VOI) were developed in the field of economics during the late 1960s (Howard, 1966, 1968). The aim was to resolve limitations in decision-making under uncertainty by judging whether it would be rational to invest in additional information prior to making a decision. Prior beliefs of a decision-maker are significant when assigning value to information and this value rises when the consequences of making a wrong decision are important. However, if a person is hesitant, any additional information is valuable to make the decision.

At its core, technology transfer is a cost–benefit exchange that businesses need to make when they decide to invest in any kind of new technology products expectedly exploitable. In that sense, technology transfer is clearly a process of decision-making. Standard economic theory assigns a value to information based solely on its ability to improve decision-making, assuming information generates a positive value if it changes behavior.

FIGURE 4
INFORMATION REQUIRED IN ORDER TO PROMOTE AN INNOVATION PROJECT (MODIFIED FROM VEGA-GONZÁLEZ, L.R., ZANELLA, R., BRUCE, N., 2018, P. 52)



Nevertheless, evidence from recent behavioral economic studies finds that information also can evoke negative emotions (Beiermann et al., 2017). This suggests information also may harm some negotiations. It is important to be aware that presenting big amounts of information could also diminish its marginal utility, particularly because this ever-increasing amount of information is often close to indistinguishable. The key is to use the proper and appropriate information during the negotiations. That is why it is convenient for the university team to have a strategy for presenting and revealing information based on the profile of the entrepreneur interested in the technology.

The Technology Transfer Time

During technology transfer negotiations, various aspects of the technological invention or product are discussed. As mentioned previously, the questions from entrepreneurs are abundant and usually related to technical, cost, financial, market and production aspects, among many others. We colloquially call this "technology transfer time." The firm must decide between seeking and licensing technology to reduce its production costs, or to produce new marketable products (Katz & Shapiro, 1985).

As in any process of human communication, when the questions are asked and the opportunity and time to provide the correct answers given, it is essential to: (1) maintain interest in the counterpart, (2) provoke new questions, (3) get the entrepreneur to analyze his opportunity costs to start a new production line or expand existing ones, and (4) develop interest in the market, its size, and exploitation.

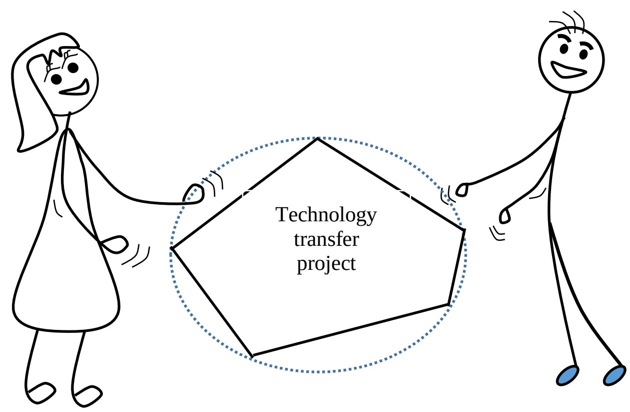
The first meetings are somewhat superficial; however, it is necessary that the representatives of the university give forceful answers as far as possible to the questions posed by the entrepreneurs. For that again, we stress that it is necessary to have the appropriate information. Possibly, in a first meeting, questions will be asked about the technical specifications of the technological product, its core technology, what problem that it solves or how it improve the processes or the daily life of individuals or organizations, and what benefits it provides in a succinct way. In a second meeting, the production requirements and the costs of scaling up and developing a new product may be discussed. For the third and subsequent meetings, it is possible to talk about costs and value of the technology, the market of segments and expected sales, regulatory and health requirements, quality and safety standards, and so on.

Almost always, when a company is interested in a university technology and wants to study the possibility of licensing it to produce it and exploit it commercially, a series of meetings are arranged between university representatives and those of the company.

As shown in **Figure 5**, the exchange of reliable technical and commercial information during negotiation meetings produces a space of feasible solutions, allowing the parties to acquire symmetrical information throughout the technology transfer time. At the end, this increases the chances of reaching an agreement on the value of the technology, which is one of the fundamental aspects of a licensing agreement.

The value of a technology also has to do with its level of maturity (Technology Readiness Level). The contribution of the information generated and captured throughout the technological development is very important for the measurement of the technology's TRL. Nearly always, technologies with TRL of 7 are progressed enough for transfer to industry. Nevertheless, after scaling and new product development activities, technology products can reach higher TRL levels (Straub, 2015).

FIGURE 5
BUILDING A SPACE OF FEASIBLE SOLUTIONS



CONCLUSION

Having reliable and appropriate information is of utmost importance during the negotiations that take place in the technology transfer meetings between the representatives of the university and the companies. In addition, having technical information, market production information, life cycle technology path, costs, sales forecasts throughout technological development, allows making decisions about the progress of the project and defining whether it is necessary to adjust some variables. Furthermore, information allows the university to define the best intellectual property strategy to follow, the form that the final products should take, their options and, in some cases, even make determinations on the term and closure of the project.

The university team must have sufficient and reliable information during technology transfer negotiations in order to offer timely answers to company questions and avoid delays while the information is being developed and/or obtained. When there are excessive delays in responses, it is very easy to lose the interest of entrepreneurs. However, when there is a good exchange of information, a feasible solution space can be reached in such a way that by sharing the information, a symmetric negotiation is established that can lead to an understanding between the parties to define the final value of the technology. This is a fair procedure, in which all parties win, including society and end consumers.

Finally, the components of the technology value comprise not only frontier scientific principles applied during technological research and development (R&D), which are transformed into the tangible material elements of technology such as the hardware and software of devices, systems, instruments, processes, etc. Kamien and Tauman (1986) state that patents also provide an inventor the opportunity to realize a profit on his investment in research and development; hence, intangible elements, such as intellectual property titles and, of course, the technical, technological, economic, and financial information, are related. Naturally, the technological product embodies all this knowledge and, therefore, acquires high value and utmost importance. In short, the value of a technological package can basically and mainly comprise four items: (1) hardware, (2) software, (3) intellectual property, and (4) the appropriate information. Of course, there may be other elements that add value to the technology but these are mostly of marginal value.

ACKNOWLEDGEMENT

Translated & edited by American Publishing Services (https://americanpublishingservices.com/).

ENDNOTE

1. Available in México but, notably, not in the United States, United Kingdom, or Canada (WIPO, 2016)

REFERENCES

Aguilera, H.R.M. (2011). *Identidad y diferenciación entre método y metodología. Estudios Políticos núm. 28 Centro de Estudios Políticos*. Universidad Nacional Autónoma de México, Facultad de Ciencias Políticas y Sociales, pp. 81–103. ISSN: 0185-1616

Alfonso, L., Mukolwe, M.M., & Di Baldassarre, G. (2016). Probabilistic Flood Maps to support decision-making: Mapping the Value of Information. *Water Resour. Res.*, *52*, 1026–1043. doi:10.1002/2015WR017378

Amer, M., & Daim, T.U. (2010). Application of technology roadmaps for renewable energy sector. *Technological Forecasting & Social Change, 77*, 1355–1370. doi: 10.1016/j.techfore.2010.05.002

Arden, W.M. (2002). The International Technology Roadmap for Semiconductors— Perspectives and challenges for the next 15 years. *Current Opinion in Solid State and Materials Science*, *6*, 371–377.

Beiermann, J., Jones Ritten, Ch., Thunström, L., & Ehmke, M. (2017). Measuring the value of information – revealed preferences for country of origin information. *Journal of Behavioral and Experimental Economics*, *71*, 96–104. http://dx.doi.org/10.1016/j.socec.2017.10.002

Carlsson, B., & Fridh, A.C. (2002). Technology transfer in United States universities. *Journal of Evolutionary Economics*, *12*(1–2), 199–232.

Gaceta UNAM. (2019, March 28). *Acuerdo por el que se establecen los Lineamientos Generales sobre Transferencia de Tecnología y de Conocimiento en la Universidad Nacional Autónoma de México* (p.22).

Gallini, N., & Wright, B.D. (1990). Technology Transfer under asymmetric information. *RAND Journal of Economics*, *21*(1), 147–160. Retrieved from http://www.jstor.org/stable/2555500

Geum, Y., & Park, Y. (2013). The state-of-the-art of public-sector technology roadmaps: A taxonomical approach to energy technology roadmaps. *Science and Public Policy*, *40*, 327–339. doi:10.1093/scipol/scs108

Geum, Y., Lee, S., & Park, Y. (2014). Combining technology roadmap and system dynamics simulation to support scenario-planning: A case of car-sharing service. *Computers & Industrial Engineering*, *71*, 37–49. http://dx.doi.org/10.1016/j.cie.2014.02.007

Gülbahar, Y. (2007). Technology planning: A roadmap to successful technology integration in schools. *Computers & Education*, *49*, 943–956. doi:10.1016/j.compedu.2005.12.002

Gummesson. (1988). Qualitative Methods in Management Research. *Chartwell Learning & Development Limited*, p.202. ISBN 0862381975, 9780862381974

Howard, R.A. (1966). Information value theory. *IEEE Trans. Syst. Sci. Cybern.*, *2*(1), 22–26.

Howard, R.A. (1968). The foundations of decision analysis. *IEEE Trans. Syst. Sci. Cybern*., *4*(3), 211–219.
Kamien, M.I., & Tauman, Y. (1986). Fees versus Royalties and the Private Value of a Patent. *Quarterly Journal of Economics*, *101*, 471–492. Oxford University Press. Retrieved from https://www.jstor.org/stable/1885693
Katz, M., & Shapiro, C. (1985). On the Licensing of Innovations. *The RAND Journal of Economics*, *16*(4), 504–520. Retrieved from http://www.sfu.ca/~wainwrig/Econ400/How-to-License-Innovation-Katz-Shapiro.pdf
Kostoff, R.N., Boylan, R., & Simons, G.R., (2004). Disruptive technology roadmaps. *Technological Forecasting & Social Change*, *71*, 141–159. doi:10.1016/S0040-1625(03)00048-9
Lee, S., & Park, Y. (2005). Customization of technology roadmaps according to roadmapping purposes: Overall process and detailed modules. *Technology Forecasting & Social Change*, *72*, 567–83.
Lee, S.K., Mogi, G., & Kim, J.W. (2009). Energy technology roadmap for the next 10years: The case of Korea. *Energy Policy*, *37*, 588–596. doi:10.1016/j.enpol.2008.09.090
Letaba, P.T., & Pretorius M.W. (2021). Toward Sociotechnical Transition Technology Roadmaps: A Proposed Framework for Large-Scale Projects in Developing Countries. *IEEE Transactions on Engineering Management*. In press.
Lockett, A., Wright, M., & Franklin, S. (2003). Technology transfer and universities' spin-out strategies. *Small Business Economics*, *20*(2), 185–200.
Lovell, E.B. (1968). *Domestic Licensing Practices*. The Conference Board, Experiences in Marketing Management, No. 18.
Lu, H.P., & Weng, C.I. (2018). Smart manufacturing technology, market maturity analysis and technology roadmap in the computer and electronic product manufacturing industry. *Technological Forecasting & Social Change*, *133*, 85–94.
Lucas, L.M. (2006). The role of culture on knowledge transfer: The case of the multinational corporation. *The Learning Organization*, *13*(2–3), 257–275.
Martin, L. (2012). Understanding the Value of Business Information. In M.K. Macauley (Ed.), *The Value of Information Methodological Frontiers and New Applications in Environment and Health* (Chapter 3). Ramanan Laxminarayan. ISBN 978-94-007-4838-5; ISBN 978-94-007-4839-2 (eBook). DOI 10.1007/978-94-007-4839-2
Martínez, C. (2006). El método de estudio de caso: Estrategia metodológica de la investigación científica. *Pensamiento & Gestión*, *20*, 165–193. Universidad del Norte Barranquilla, Colombia. Retrieved from https://www.redalyc.org/pdf/646/64602005.pdf
Meyer, C.B. (2001). A Case in Case Study Methodology. *Field Methods*, *13*(4), 329–352.
Nguyen, T.D.N., & Aoyama, A. (2015). The impact of cultural differences on technology transfer Management practice moderation. *Journal of Manufacturing Technology Management*, *26*(7), 926–954. DOI: 10.1108/JMTM-09-2013-0130
Niv, Y., & Chan, S. (2011). On the value of information and other rewards. *Nature Neuroscience*, *14*(9), 1096–1097.
Petrick, I.J., & Echols, A.E. (2004). Technology roadmapping in review: A tool for making sustainable new product development decisions. *Technological Forecasting & Social Change*, *71*, 81–100.
Rahal, A.D., & Rabelo, L.C. (2006). Assessment Framework for the Evaluation and Prioritization of University Inventions for Licensing and Commercialization. *Engineering Management Journal*, *18*(4), 28–36. DOI: 10.1080/10429247.2006.11431711
Straub, J. (2015). In search of technology readiness level (TRL) 10. *Aerospace Science and Technology*, *46*, 312–320.
Teece, D.J. (1977). The Multinational Corporation and the Resource Cost of International Technology Transfer. *The Economic Journal*, *87*(346), 242–261. Cambridge: Ballinger Press.
Tellis, W.M. (1997). Introduction to Case Study. *The Qualitative Report*, *3*(2), 1–14. https://doi.org/10.46743/2160-3715/1997.2024
Vega-González, L.R., Zanella, S.R., & Bruce, D.N. (2018). Knowledge Energy, recurrent learning and the transformation of an R&D institution in a Mexican Public University. *Case Studies in Business*

and Management, *5*(2), 41–59. Macrothink Institute. http://dx.doi.org/10.5296/csbm.v5i2.13628. ISSN 2333-3324.

Volberda, H.W., Ilan Oshri, I., & Mom, J.M.T. (2012). Technology transfer: The practice and the profession. *Technology Analysis & Strategic Management*, *24*(9), 863–869. DOI: 10.1080/09537325.2012.718662

WIPO. (2016). *Where can Utility Models be Acquired?* Retrieved from https://www.uspto.gov/web/offices/ac/ido/oeip/taf/data/patdesc.htm

Yin, R.K. (2003). *Case Study Research Design and Methods* (3rd Edition., p.312). Sage Publications.