Evaluation Tool for Technological Project Selection in the Early Stage of Innovation: Experiences from the Development of the Application in a Technology Transfer Office

David Güemes-Castorena, Gonzalo Iván Uscanga-Castillo
Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM) Campus Monterrey, Nuevo León, México

Abstract--**A Technology transfer office needs to assess their technological project portfolio and are faced with the dilemma of selecting the most promising ones. Moreover, at the earliest stages of technology exist higher technical and market uncertainties as same as unsatisfactory evaluation tools to support the decision. Within this context, we already developed an evaluation tool that aims to assess the portfolio and supports the decision. However, there are some important questions related to the usability and the relevance and other benefits of the evaluation tool.**

This paper focuses on the experiences, the feedback from applicants/evaluators, and the lessons learned due to the application of the evaluation tool to a technology transfer office project portfolio in order identify the relevance of the evaluation tool as well as to improve the performance and its impact. This study comprises the problems associated with applying the tool, interpreting the results obtained, and foresees the future for the evaluation tool.

I. INTRODUCTION

Recognizing the importance of university related scientific and technology research as an important source of long-term economic growth and technological innovation, and faced with the pressure to speed up new product delivery, an ever decreasing product life cycle, and a fast technological obsolescence, U.S. corporations have significantly increased their sponsorship and financial support of academic research. As a consequence, university technology licensing has increasingly been looked at as a complementary and attractive solution to gain insights into new technology innovations [22]. So universities has to transfer technology to those who can potentially commercialize hence universities establish specialized intermediary structures. University Technology Transfer Offices (TTO's) are typically the most important intermediaries in the commercialization of university research [3]. However, many of the studies on TTO's discuss the methods or best practices in determining the potential commercialization success of a university invention a priori, and involve many methods and parameters needed to evaluate these technologies, but they rarely mention the process of valuation; in fact in a survey realized to 100 University Licensing Offices [11], only 14 responded that they use a methodology of a standard valuation process.

Based on this context, Güemes et al [10] developed an evaluation tool that aims in the process of evaluation and supports the decision. Conscious that achieve the goal of building an effective and simple evaluation tool is an ambitious objective, we persist on the purpose to improve the evaluation tool, then this paper focuses on the experiences, the feedback from applicants/evaluators, and the lessons learned due to the application of the evaluation tool in order to improve it.

II. LITERATURE REVIEW

At different stages of the innovation funnel, the technology has different characteristics and needs and stages [7]; one of them, is the Early Stage Technologies (EST); however there are not clear definitions readily available. For example, Razgaitis [23] said that EST means potential new business opportunities that are at an early or mature state of R&D and not yet to the point of having been productized and introduced commercially. Otherwise, Dissel M. et al [7] define that an early stage technology can be determined by assessing the technical and market uncertainty of a specific technology; If these are high then the technology is in an early stage. In our case the most important characteristics in EST are: 1) the technology has not been commercialized and 2) more resources are needed to confirm its feasibility and have not passed the standards and regulations. This is the context of technologies analyzed through our evaluation tool therefore only some variables and tools are adequate. Thus, brief descriptions about TTO´s give us an understanding about who is the evaluation tool user. Later we provide a conceptual understanding of what a technology roadmap is and why this technique support our evaluation tool. Finally, the most representative evaluation tools found are described in order to integrate all those elements through our proposal and achieve the objective.

A. University Technology Transfer Offices

Technology transfer is a term used to describe a formal transfer of rights to use and commercialize new discoveries and innovations resulting from scientific research to another party. Universities typically transfer technology through protecting (using patents and copyrights), then licensing new innovations [2].

TTO's personnel administer the commercialization process of a university's intellectual property (IP), defined as patents, copyrights, trademarks, various know-hows, and related assets. At the most general level, TTO personnel are responsible to (a) evaluate and valuate disclosures of new discoveries; (b) seek legal protection for the technology, primarily through patenting; (c) sell licensing agreements to industry; and (d) collect royalty, oversee, and enforce contractual agreements with licensees [18]. Within this

context, TTO's need to assess their technological project portfolio and select the most promising projects. In other words, the TTO´s aim at choosing the best project with the aim of receiving the resources for development [22].

B. Technology roadmap

Technology roadmapping represents a powerful technique for supporting technology management and planning, especially for exploring and communicating the dynamic linkages between technological resources, organizational objectives and the changing environment [19]. It is a technique to structure and assist brainstorming based on the future potential of technologies. It is being used in industry to support a variety of strategic goals [15,16].

The main benefit of technology roadmapping is that it provides information to make better technology investment decisions by identifying critical technologies and technology gaps and identifying ways to leverage R&D investments [9]. It does this by:

- Identifying critical technologies or technology gaps that must be filled to meet product performance targets.
- Identifying ways to leverage R&D investments through coordinating research activities either within a single company or among alliance members.

Roadmapping supports the valuation of early stage technologies as it plots the potential future of the technology against a timeline and clarifies the enablers and barriers to value creation. Thus a better judgment on the future value of the technology can be extracted from the roadmap [7].

The roadmapping approach includes two main components, namely the application (i.e., the roadmapping process) and the result of the application (usually a map known as the roadmap). Therefore, the word "roadmap" represents a summary of science and technology plans in the form of maps, and the roadmapping process is the development of this roadmap. Although a roadmap can be presented in several forms, it usually includes a multilayer graphical representation of a plan that connects technology and products with market opportunities (See Figure 1) [5].

As a result of technology roadmapping [9], a company or an industry can make better investment decisions because it has better information to:

- Identify critical product needs that will drive technology selection and development decisions.
- Determine the technology alternatives that can satisfy critical product needs.
- Select the appropriate technology alternatives.
- Generate and implement a plan to develop and deploy appropriate technology alternatives.

An additional benefit is that as a marketing tool, a technology roadmap can show that a company really understands customer needs and has access to or is developing (either internally or through alliances) the technologies to meet their needs [9].

C. Evaluation Tools

There are some evaluation-tools available in the market, some of them offer through a consulting service or like software. In this section, we review four evaluation tools that were used as benchmarks in this study in order to identify similarities as well as identify opportunities areas that could be include in our proposal.

1) MyAdvisor™ – Technology Assessment

MyAdvisor™ is a software [24] which permits the evaluator to sort by relevance from up to eight project proposals, based on the results obtained by each project by answering 10 questions which cover the most relevant criteria in technology innovation.

The software could be used to manage the life cycle product, to standardize the project selection process as well as to make supported decision in technology innovations.

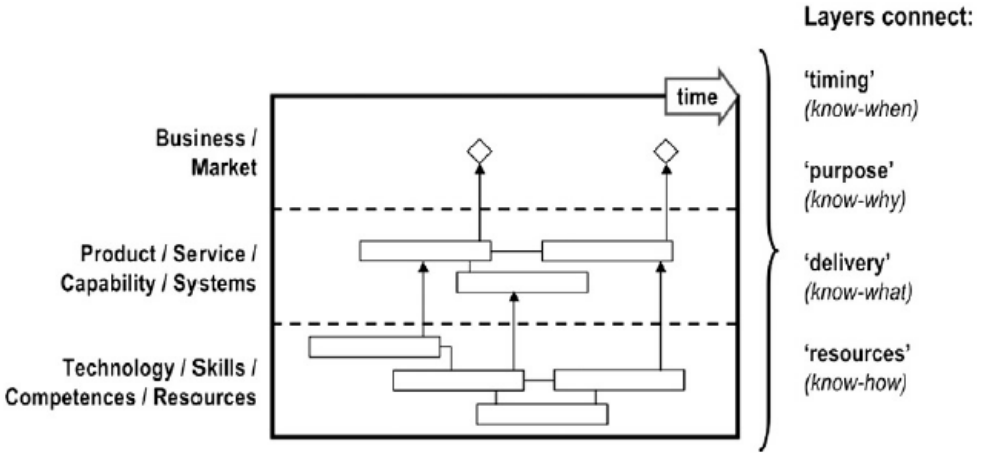

Figure 1. Generalized technology roadmap architecture [19]

Results report is basically exhibited in two graphics:

a. Technology evaluation graph, which shows the localizations of the technology between to axis; commercial strength (x axis) and technology strength (y axis), where the best position (greatest possibilities of success) is in the upper right corner (great commercial and technological strength).
b. Technology profile graph, which shows the results obtained by answering each one of the questions. This bars graph allows to identify specific strengths and opportunities as same as the weight of each question.

2) IDEKO - Specialized services to support innovation in SMEs

IDEKO is a technology center focus in manufacturing technologies and industrial production integrated to "la Alianza Tecnológica IK4" [12]. Its activities involve identifying and analyzing opportunities, products, design and develop business units, productive process and problem solution through technology service support as same as consulting and equipment supply.

IDEKO owns a complete model named "explotación de resultados" (exploitation of results) which is well documented and organized tool in order to achieve strategic goals. Within this model are two stages: 1) the characterization and 2) analysis.

IDEKO's tool is integrated by four sections: 1) Idea analysis, 2) Design of intellectual property, 3) DAVALOR (Value analysis) and finally, 4) Exploit plan. Within idea analysis section are four categories: Marketing, Commercial, Technical and strategy fit. The strategy fit category is an original difference versus the rest evaluation tools. It should be mentioned that strategy fit is one of the variables identify by Güemes et al [10] however is not included in the evaluation tool due to most of technological projects in early stage are not created by established firms so it's not necessary to align or fit project scope to any strategy firm.

3) Isis Innovation - Commercializing Academic Research

Isis Innovation [13] is a wholly-owned subsidiary of the University of Oxford, managing technology transfer and academic consulting for Oxford, and providing consulting advice to clients around the world. Isis manages the University's intellectual property portfolio, working with University researchers on identifying, protecting and marketing technologies through licensing, spin-out company formation, consulting and material sales. By means of Isis courses that we get access to Isis knowledge about its tool and recommendations in order to evaluate early stage technologies.

Isis use a structured and well defined process that brings good results thus its customer portfolio is growing around the world. This knowledge give us a reference to discuss our finds as same as our assumptions.

The first stage of Isis process consists on filling the forms directly related to our study objective, which are: 1) Innovation Fund Form and 2) IP1 and IP2 Due Diligence. These forms have a strong focus on intellectual property protection and patent conditions on the other hand, there are not using technology roadmap or graphical results from the evaluation. So we consider this, as an opportunity to implement in our work.

4) Cambridge Enterprise Limited

Cambridge Enterprise Limited [4] is a wholly owned subsidiary of the University of Cambridge. It is responsible for commercialization arrangements for University discoveries. Similar to Oxford technology transfer office, Cambridge Enterprise owns a structured and well defined technology commercialization process.

Inside Cambridge process, the office receives the invention disclosure form from an applicant so each application is assigned to an expert by sector. Subsequently, the expert perform the evaluation and analysis of the technology as same as the exploit plan. As can be seen in this process applicant has the personal support. Nevertheless implies more resources, increasing the operation cost.

In summary, each evaluation tool has strengths and weakness so we identified what to include and what to avoid in our proposal in order to get a simple, practical and complete evaluation tool.

III. METHODOLOGY

To construct the evaluation tool, Güemes et al [10] designed, planned and executed the following process (Figure 2). It starts through a literature review aiming to identify variables or key determinants to commercial success as same as review the technology valuation methods and current available evaluation tools.

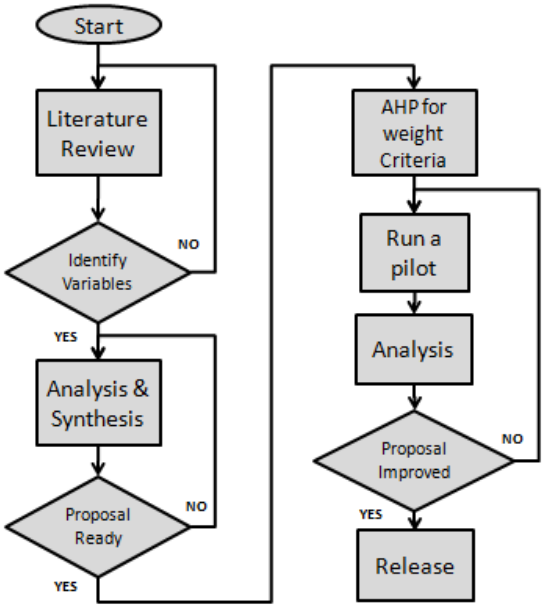

Figure 2 Process to construct the evaluation tool

As literature review result, Güemes et al [10] identified 279 variables, however an evaluation tool that includes one question for each variable will end up tedious and weary. Thus a synthesis and analysis was done to merge variables in related criteria in order to simplify the amount of information. The purposes are five criteria that group the total of variables. Which are:

- **Technology**. In this criterion, we describe the technology behind the invention in a manner that allows us to understand what it is, how it works, what is the value proposition, the industrial application and the novelty and the non-obvious.
- **Investment Perspective.** In this criterion, we describe the initial investment estimated also to mention and if you have economic support as well as the estimated demand.
- **Intellectual Property**. This criterion helps to clarify the ownership of the invention, and to identify issues which will need to be addressed downstream; to provide important record of the date of the invention, details of persons involved, reasons of the research (publish or patent which can become important in future patent process).
- **Market.** This criterion identifies if the invention responds market needs, the alignment with industry trends, and the awareness of companies who may have interest in the invention.
- **Roadmap.** In this criterion we ask about the plan based on a timeline in order to develop the invention. It means personnel skills, equipment, the facilities, the materials and milestones.

Once synthesized the five criteria, Güemes et al [10] processed the questions needed in order to cover the key success variables previously identified. As result, we developed a first evaluation tool. This first proposal was sent to eleven experts in order to receive feedback. Due to expert comments some changes and corrections were done such to merge two questions in only one as same as to add more questions.

Otherwise, one of the investigation objectives was to understand what the most important variables are, so we proposed to answer through pair comparisons between the five criteria using an Analytical Hierarchical Process (AHP). Using pair comparison, it was identified the Market criterion as the most relevant criterion with 33.8% followed by technology criterion with 18.8% then roadmap 18.4% intellectual property 15.4% finally investment perspective with 13.6%. These numbers came from a panel of eleven experts which compared according to their experience each single criterion versus the rest in a scale from 1 to 9. Figure 3 shows an example filled by an expert by pair comparison in order to identify the most important criterion. This information was filled and processed through *expertchoice*® [6] which is a software that uses AHP.

	Investment Perspective	Intellectual Property	Market	Roadmap
Technology	4.6	1.4	2.5	3.2
Investment Perspective		3.2	3	1.8
Intellectual Property			2.8	3
Market				3
Roadmap				

Figure 3 Pair comparison matrix

Before to run a pilot, the evaluation tool was placed into a web site so it is available all the time and anywhere, whence it was programmed on ASP.NET 4.0 and its database on POSTGRE 9.2. The system was developed with capability to draw the roadmap based on the information loaded by the proponent. So, the proponent must answer questions related to the following kind of resources: skills, materials, equipment, infrastructure and milestones required to achieve it. According to the requirements based on time, the evaluation tool builds and displays the roadmap (Figure 4).

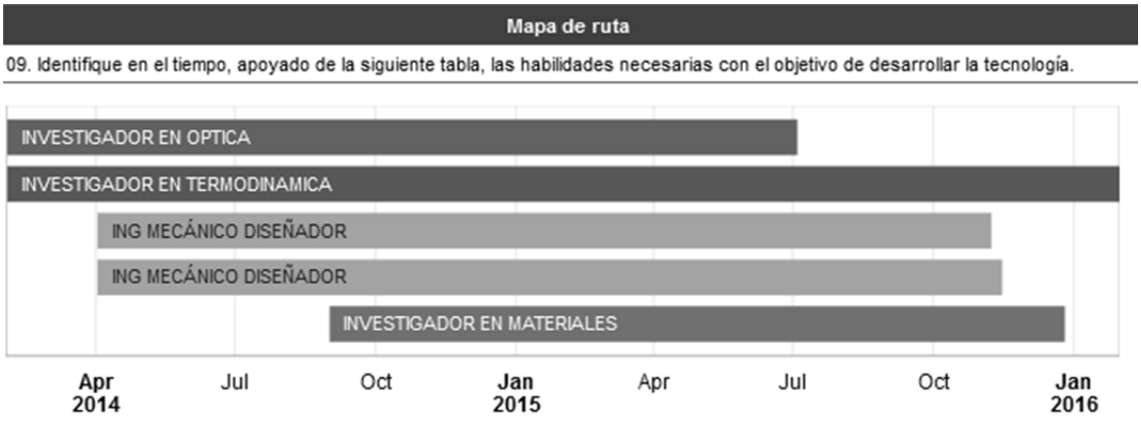

Figure 4 Example of resources requirements base on time

Another important feature is the capability of exhibit the results in a visual way through a dashboard interface making the interpretation easier for the users (both the proponent and evaluators). See Figure 5.

Figure 5 Examples of the evaluation dashboard

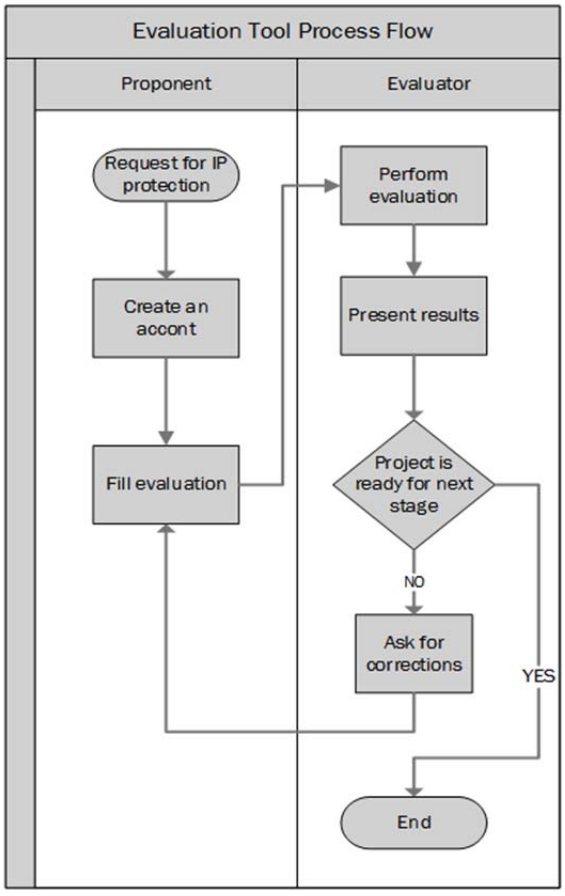

Figure 6 Evaluation tool process flow

After the evaluation tool was built, we proceeded to run pilot test involving proponents and evaluators; the Figure 6 shows the operational process flow: 1) proponent asks the OTT to start an IP protection process, 2) proponent fills out the evaluation on-line, 3) evaluator assesses the proposal supported by the evaluation tool, 4) according to the results, the evaluator answers the following question: is the project ready to go to next stage? If it is, then the project goes to the next stage; elsewhere a feedback is sent to the proponent in order to improve his proposal.

Based on the experiences from pilot runs, we received feedback from applicants/evaluators, so we could analyze the lessons learned.

IV. DISCUSSION

The evaluation tool aims to assess technological projects at the early stage of technology, to select the most promised ones and to support the decision. However, what will happen if the experts do not agree with the roadmap? The evaluation process (Figure 6) was planned to be an iterative procedure, it means that a project proposal rejected in its first trial could be improved based on the evaluator's corrections. So the project could be re-evaluated pending to be approved.

Our evaluation tool was built based on the variables or key success factors which were identified through process shown in Figure 2. Thus our proposal for evaluation contains five criteria that group the total of variables.

The results showed that *Market* criterion is the most relevant variable with 38.8%. This means that projects oriented to answer market necessities or supply identified demands have more possibilities of commercial success than those not oriented. For example, MyAdvisor software uses the commercial strength (X-axis) as an important variable for evaluate projects too. Meanwhile Paul Ahlstrom y Nathan Furr [1] affirm that an appropriate customer identification and the demand supply is the key to achieve the success in a firm. Thus, our findings are consistent with other studies mentioned.

On the other hand, we identified that authors like Probert D. et al [20] stress the importance of "soft" approaches to supplement quantitative assessment techniques, especially in the EST. Hence Non-quantitative techniques that attempt to structure reasoning and serve as an aid to decision makers in shaping their judgment, such as the roadmaps [8]. So our proposal involves the technological roadmapping in contrasts to benchmarked evaluation tools.

However, it was found that evaluators and proponents need to get informed about the technology roadmap then a technology roadmap quick guide was done base on recognized authors [5,7,9,15-17,19,21] with the purpose of explain how this technique could be use it and what are benefits and goodness could be extracted from it.

It's important to mention that roadmap supports the applicant because it helps to identify the gaps between milestones and the resources. Maybe there are some missing resources necessaries to get the objectives or applicant never asked to himself, what should he/she need or what he/she already has it? Therefore applicant can start to work in order to overcome the obstacles. Additionally, the evaluators could asset the clarity of the objectives, the efforts and resources

put in place and the level of detail and knowledge of the applicant. Then roadmapping involves applicants and evaluators working together looking for what is needed in order to generate the innovation.

During pilot runs, proponents commented on the on-line tool format opportunities like paraphrase the questions; conversely evaluator feedback came more critical. They identified functional opportunities like:

- To re-write three questions and one attribute due to miscommunication errors.
- To edit the questions more specifically to avoid ambiguities.
- To export an evaluation report.
- Auto rank the project portfolio evaluated.

Evaluators had problems understanding the roadmap; this situation made evident the requirement to prepare a fast-guide to roadmap before evaluator start using the tool. At this point, the developers of the evaluation tool had to explain the usefulness of the roadmap and its visualization to the evaluators, who understood the benefits of it.

It´s important to mention that the evaluation tool has been applied in Mexico´s context and the pair comparison was done by Mexican experts only. However, as we mentioned before our results are consistent with other authors [1,14,24,25]. Another constraint is that Güemes et al [10] focus to construct an easy use and simple tool only for early stage technologies, then some variables were not included; most of the latter related to mature or late stage of technology development like "fitness to firm strategy/culture".

According to study limitations some pending activities are: to extend the number of experts to perform the pair comparison, and/or involve experts from other countries, so this reveals if a gap exists between the new weights and those exhibited here. Also, it's important to add a discussion process before the decision be made because the evaluators only see what was posted on the on-line platform; then is important to clarify the information as much as possible. Additionally, it could become interesting to specialize the evaluation tool in order to customize it to different types of projects: biotechnology, information technology, manufacturing, etc.

V. CONCLUSION

The main difference by our evaluation tool is that it integrates the uses of technology roadmap as part of the evaluation process. It helps, to construct the technology roadmap in order to identify technology gaps that must be filled, as same as, identifying ways to leverage R&D investments through coordinating research activities. Thus, roadmapping supports the valuation of early stage technologies due to clarify the enablers and barriers to value creation.

The process conceived to construct the tool enabled us to make mistakes, to identify our opportunities, and to learn about them, and to continuously improving the evaluation tool. The process was accompanied with the users of the TTO which helped us to make these iterations faster and to continue with the process in a smooth way.

It is worth mentioning that this tool helps to leverage the first-step of the evaluation which may involve many resources –highly qualified experts – in other organizations, as well as to provide a standardized process –which many TTOs lack of.

REFERENCES

[1] A Furr, N. R., & A Ahlstrom, P. B. (2011). Nail it Then Scale it: The Entrepreneur's Guide to Creating and Managing Breaththrough Innovation: NISI Institute.

[2] AUTM. (2014). AUTM | FAQs. Retrieved 7/01/2014, from http://www.autm.net/FAQs.htm#1

[3] Caldera, A., & Debande, O. (2010). Performance of Spanish universities in technology transfer: An empirical analysis. Research Policy, 39(9), 1160-1173.

[4] Cambridge_Enterprise. (2014). Company information – Cambridge Enterprise. Retrieved 9/01/2014, from http://www.enterprise.cam.ac.uk/company-information/

[5] Carvalho, M. M., Fleury, A., & Lopes, A. P. (2013). An overview of the literature on technology roadmapping (TRM): Contributions and trends. Technological Forecasting and Social Change, 80(7), 1418-1437.

[6] Choice, E. (2012). expertchoice® for Collaborative Decision Making. Retrieved 10/03/2013, from http://expertchoice.com/

[7] Dissel, M., Farrukh, C., Probert, D., & Phaal, R. (2005). Evaluating early stage technology valuation methods; What is available and what really matters.

[8] Dissel, M. C., Phaal, R., Farrukh, C. J., & Probert, D. R. (2009). Value roadmapping. Research Technology Management, 52(6), 45-53.

[9] Garcia, M., & Bray, O. (1997). Fundamentals of Technology Roadmapping.: Strategic Business Development Department Sandia National Laboratories.

[10] Guemes-Castorena, D., Fierro-Cota, R. M., & Uscanga-Castillo, G. I. (2013, July 28 2013-Aug. 1 2013). Technological project portfolio selection in the front end of innovation for a Higher Education Institute: The development of an evaluation tool. Paper presented at the Technology Management in the IT-Driven Services (PICMET), 2013 Proceedings of PICMET '13:.

[11] Hallam, C. R. A., Leffel, A., & Chinea, I. (2011). Early phase technology management valuation practices by university licensing offices in the United States: Empirical data from a survey of the top 100 organizations. Paper presented at the PICMET: Portland International Center for Management of Engineering and Technology, Proceedings.

[12] IDEKO. (2013). IK4 IDEKO Research Alliance. Retrieved 10/03/2013, from http://www.ideko.es/

[13] Isis_Innovation_Ltd. (2014). Isis Innovation: technology transfer from the University of Oxford. Retrieved 9/01/2014, from http://www.isis-innovation.com/

[14] Kang, J., Gwon, S. H., Hong, S., Kim, Y., & Cho, K. (2011). Determinants of the technology commercialization of the government-sponsored firms: Empirical evidence from Korean manufacturing. Paper presented at the PICMET: Portland International Center for Management of Engineering and Technology, Proceedings.

[15] Kappel, T. A. (2001). Perspectives on roadmaps: How organizations talk about the future. Journal of Product Innovation Management, 18(1), 39-50.

[16] Kostoff, R. N., & Schaller, R. R. (2001). Science and technology roadmaps. IEEE Transactions on Engineering Management, 48(2), 132-143.

[17] M, K. T. (2000). Management of technology: the key to competitiveness and wealth creation. U.S.: Mcgraw-Hill.

[18] Markman, G. D., Phan, P. H., Balkin, D. B., & Gianiodis, P. T. (2005). Entrepreneurship and university-based technology transfer. Journal of Business Venturing, 20(2), 241-263.
[19] Phaal, R., Farrukh, C. J. P., & Probert, D. R. (2004). Technology roadmapping—A planning framework for evolution and revolution. Technological Forecasting and Social Change, 71(1–2), 5-26.
[20] Probert, D., Farrukh, C., Dissel, M., & Phaal, R. (2011). Towards a process framework for assessing the potential value of technologies.
[21] Probert, D., & Radnor, M. (2003). Technology Roadmapping: Frontier Experiences from Industry-Academia Consortia. Research-Technology Management, 46(2).
[22] Rahal, A. D., & Rabelo, L. C. (2006). Assessment framework for the evaluation and prioritization of university inventions for licensing and commercialization. EMJ - Engineering Management Journal, 18(4), 28-36.
[23] Razgaitis, R. (1999). Early-Stage Technologies: Valuation and Pricing: John Wiley & Sons.
[24] Solutions, P. E. (2013). MyAdvisor™ - Technology Assessment. Retrieved 10/03/2013, from http://progrid.info/software/myadvisor%E2%84%A2-technology-assessment
[25] WIPO_World Intellectual Property. (2011). Valuation of Early Stage Technologies: How to Reach a Starting “Price” for Negotiating a TT Agreement. Noordwijk, Holanda.