Paper to be presented at the

DRUID Society Conference 2014, CBS, Copenhagen, June 16-18

A Criteria-based Approach for Evaluating Innovation Commercialisation

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Abstract

This study attempts to provide a criteria-based approach that can be used to evaluate the potential for technology transfer and commercialisation of a new technology from university research. More specifically, this study offers the critical factors for assessing marketability and feasibility of an innovation for the commercialisation and technology transfer process. The Delphi technique has been used to refine and categorise assessment criteria identified from various models and frameworks that emerged from literature. Proposed categories of criteria that are found to be important in the evaluation and assessment of a new technology for the commercialisation purpose include: Technological Readiness; Legal and Regulatory; Social Benefits and Impact; Economic and Market Factors.

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Keywords: Technology assessment, research commercialisation, technology transfer, evaluation criteria, Delphi method.

1. Introduction

Technology Transfer (TT) and commercialisation of university research outcomes are highly expanding field of knowledge attracting a great deal of interest from institutions and industries alike (Perkmann, et al., 2013 & Reisman, 2005). Many firms choose to acquire new technologies and capabilities from academic institutions and other firms in different industries to maintain and enhance their competitiveness (Ranft & Lord, 2002). For technology transfer and commercialisation to be as successful and beneficial as possible, evaluating its potential is necessary as it helps minimise risks associated with failure of the transfer which could result in huge losses to the parties involved. Based on the increasing importance of university contribution to commercialisation and the requirement of evaluation to reduce risk, this paper examines various assessment criteria that can be used to evaluate a new technology for the commercialisation and technology transfer purpose.

The terms 'technology transfer' and 'innovation commercialisation' are often used synonymously, although strictly speaking there are important differences in their precise meanings and variations among scholars in their usage. In the scholarly literature, the term 'technology transfer' refers mainly to 'the movement of know-how, technical knowledge, or technology from one organisation to another' (Bozeman, 2000, p. 629), although the most common use is in relation to the transfer of inventions and associated 'know-how' from research organisations to research users. Technology Transfer (TT) usually involves the participation of two parties, a transferor and a transferee, but in the bigger picture it can involve companies, organisations (including universities) or even an entire nation, and there can be more than one discipline involved (Reisman, 2005). Technology transfer from universities in particular has gained importance after the introduction of the Bayh-Dole Act in The United States in 1980. This is due to the fact that there is valuable research originating from many universities that has the potential to produce good products; but because the primary goal of universities is not commercialisation, valuable research is sometimes lost. This has led to many organisations getting involved through industry linkages, to encourage universities to continue their research with a commercial goal in addition to the academic milestones. This is especially true for university related research as it is being recognised as an important source of innovation and economic development, and this is verified by the fact that various industries are entering collaborations with universities and funding academic research (Rahal & Rabelo, 2006).

'Innovation commercialisation' mainly refers to the process of turning scientific discoveries and inventions into marketable products and services, generally through licensing patents to companies or by the creation of 'start up' companies that depend on the assignment to them of university intellectual property (IP). It is in this sense that the term is used in this paper. However, it should be noted that some scholars define innovation commercialisation to include research links with industry.

This paper reports the findings of a Delphi study by categorising different types of criteria that are found to be crucial for evaluating the potential of a new technology for commercialisation and technology transfer before the technology is transferred, namely, ex-ante evaluation. The criteria at first are selected from relevant literature and then modified, using expert opinion and the Delphi method, so as to keep the criteria relevant with the present requirements. These criteria can then assist decision makers in assessing the potential of technological transfer readiness of a particular technology, along with the benefits and demerits, to assist in the assessment of the potential viability of the university's technologies for transfer and commercialisation.

2. Research Background

The literature on university technology transfer evaluation provides an insight into the importance of the relationship between university research, technology transfer and commercialisation process (Perkmann, et al., 2013). While numerous frameworks and models mainly arising from commercialisation and evaluation literature have been developed, the majority of them focus on the process and outcome of evaluation and therefore encompass criteria suitable for evaluating the transfer of a technology during and after the commercialisation process (Heslop et al., 2001; Geuna and Martin, 2003). On the other hand, literature on university technology transfer identified lack of comprehensive criteria that could be used to assess the commercial potential of a technology before the technology is being transferred. For instance, Howells and McKinlay's (1999) study on the commercialisation of research from European universities concluded that there was a lack of criteria and evaluation framework that are needed to help with assessing potential of new technologies emerge from university research. On the other hand, Anthony, Eyring and Gibson (2006) and Heslop et al. (2001), in their studies, emphasise the need for creating a diverse checklist for ex-ante evaluation as this will ensure that any important opportunities are not missed out. This view is the essence of this study due to the fact that picking potential winners from a vast range of opportunities derived from university research is a tricky and risky business with a high failure rate. Therefore both producers and the acquirers of the technology would benefit from a set of criteria that could help in the assessment, prediction, and identification of those technologies with above-average potential for commercial application. Thus, in this study an effort has been made to identify the core categories of criteria for the 'ex-ante' evaluation of the commercialisation process.

The role of educational institutions such as universities has experienced considerable change in relation to their roles and contributions to innovation, which has led to an increase in the types of relationships leading to knowledge creation and spill over (Gibbons et al., 1994; Howells & McKinlay, 1999). As mentioned, the Bayh-Dole Act or Small Business Patent Procedures Act introduced in the United States (USA) in 1980 helped to revolutionise how universities were involved in commercialisation, and helped improve the number of licences and patents originating from universities in the United States (for a recent assessment of this Act, see Grimaldi et al., 2011). The Bayh-Dole Act was named after Senators Birch Bayh and Robert Dole who co-sponsored the Act under President Carter. The Act influenced other countries to implement similar procedures encouraging their universities' involvement in commercial activities (Nelson, 2001; Mowery & Ziedonis, 2002; Baumel, 2009).

For instance, the last few decades have seen an increase in contribution to commercial activity from Australian universities. This is also supported by Lööf and Broström (2008) who state that much attention is given to the influence of universities in literature relating to innovation and technological change. Statistical data indicate that the higher education sector has been responsible for more than 25 per cent of all research and development conducted in the last couple of decades (Burgio-Fica, 2001; Zhao, 2004). Statistics also reveal that in the five year period between 1992 and 1997, Australian universities increased their funding from industry by some $130 million (Australian, 1999; Harman, 2001). Additionally, for the past decade Australian government has invested considerable sums in innovation and research commercialisation and in encouraging more effective links between universities and research users (Harman, 2010).

The technology transfer and commercialisation of new innovations play an important role not only for universities but also for organisations and economic development (Dority, 2003). Commercialisation of new innovations and technology transfer can occur in various ways: licensing, direct foreign investments, technical agreements, joint ventures, turnkey projects, and the purchase of equipment amongst others (Wei, 1995). Göktepe (2004) states that when technology flows from a certain stage to the next the transition is not smooth, but is usually affected by gaps such as identifying a potential application and when and how this can be turned into a marketable product, and that such gaps can break the flow of the transfer. A collection of criteria that could take all of this into consideration can help to minimise gaps and maximise the efficiency of the flow. This can be achieved through ex-ante evaluation.

The literature on the evaluation of technologies and commercialisation process covers a broad aspect of the assessment procedure. In general, evaluation can be defined as valuing the quality of an explicit methodology that can be scrutinised for its validity or simply the science of valuing (Scriven, 1981). In terms of technology transfer evaluation, Harris and Harris (2004) maintain that technology tends to be evaluated in terms of its usability and functionality from an ergonomic perspective. However, when technology is transferred from one application to another, the wider context needs to be assessed. According to Jasinki (2006), evaluation of the transfer process includes assessing the viability, gains, costs, and risks of the technology. According to OECD (1987) and Luik (2005), the important dimensions of evaluation include the scope of evaluation, the object of evaluation, the level of evaluation, the time span of evaluation, the purpose of evaluation, the criteria for evaluation and the organisation, and the resources and responsibility of evaluation. Some of the general categories of criteria identified in the literature encompass economic value, feasibility, measurement of indicators, and the potential for cross-fertilisation. Some of the methods used range from developing models and conducting surveys to micro and macro-economic case studies and statistical and econometric analyses (OECD, 1987; Luik, 2005). Evaluation can usually occur at three different levels, namely ex-ante evaluation, interim evaluation, and ex-post evaluation. Miles et al. (2006) have portrayed this in Figure 1.

Ex-ante evaluation is normally conducted before an option is chosen or implemented, to know whether it will be beneficial and whether it could be a guide on how the required goals can be achieved. On the other hand, ex-post evaluation is concerned with the results or outcomes of a project after it has been implemented and possibly completed (Miles et al., 2006). Geuna and Martin (2003) differentiate these by stating that while ex–ante evaluation is conducted to gauge the significance and chance of success, ex-post evaluation is used to assess the outcome and impact, if any. They further add that evaluation can fulfil two types of functions; namely, summative and formative (Kuhlmann, 1995). Furthermore, ex-ante evaluation can be used to assess or appraise a technology based on a set of different criteria before it is transferred from a university setting to the commercial market.

In relation to what should constitute the evaluation process, there are different views and opinions from various scholars and academics. According to Spann et al. (1995), measures of technology transfer effectiveness are not well defined or accepted, and there is a growing need for a comprehensive framework or model to evaluate and measure the process. Heslop et al. (2001) note that there are several robust tools to help determine which technologies are likely to be successful when commercialised. A few authors have suggested essential tools that can aid technology evaluation to help predict good transfers. For example, Watkins (1990) suggested elements such as the effectiveness of the technology, commercial viability, and whether the technology can be coped with. The Association of University Technology Managers (AUTM) (1994) drew attention to the lack of a protocol to aid in the evaluation of commercial feasibility for research and innovation out of laboratories based in universities. This is backed by Heslop et al. (2001) who adds that no wide-ranging study has been conducted to demonstrate how the producers of technologies evaluate or assess their knowledge for transfer. More recently, Miles et al. (2006) point out that ex-ante evaluation could provide the stepping stones for the other sets of evaluation to be conducted. For ex-ante evaluation to be conducted, a set of criteria that aid this purpose need be compiled. These are discussed in the next sections.

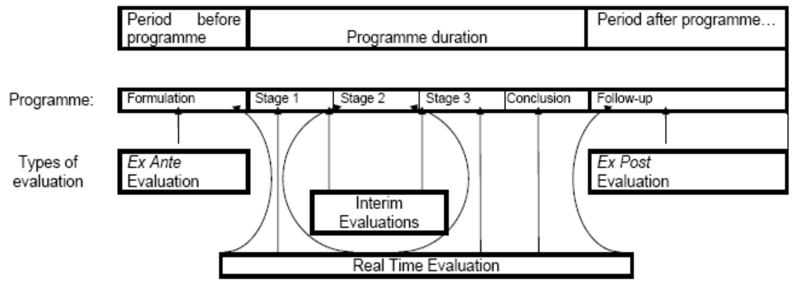

Figure 1 Levels of Evaluation (Miles et al., 2006**)**

3. Research Method

The approach of this study involves a series of steps. Firstly it is necessary to identify the criteria that are mentioned in the literature as crucial to the successful technology transfer from universities and then, through a rigor process, it is attempted to refine the criteria in order to obtain a set of the most important and robust criteria to enable efficient evaluation. Therefore in this study firstly an attempt has been made to compile the criteria from literature to build a set of the initial assessment criteria. This has been outlined in the next section. This list then was further refined and validated using the Delphi technique consisting of interviews and online questionnaires with experts involved in commercialisation and technology transfer process. To obtain the most important criteria and rate the aforementioned criteria, the Delphi method was well suited as it helped to identify the least important criteria and achieve a satisfactory level of convergence with the participation of experts (Kaynak et al., 1994; Roest, 2002).

The Delphi method was developed during the early 1950s and is based on a structured process for collecting and distilling knowledge from experts in several rounds combined with controlled opinion feedback (Roest, 2002). Delphi is a way of obtaining information from a set of experts with the aim of achieving consensus. The experts are asked a number of questions, which are then summarised and sent back to the experts anonymously to check if they would like to reconsider their answers based on the means of the ratings. The process can be repeated a number of times and this can help to augment the reliability of the results. The process involves obtaining experts' opinions and summarising them, and they are allowed to change their results so as to agree with the consensus, or their results can remain unchanged with a justification.

The Delphi method in this research consisted of recruiting a team of multi-disciplinary experts. The experts were divided into categories according to whether they were experts on technology transfer mechanisms, technology applications, technology or licensing consultants, or experts on commercialisation process (Table 1). This guaranteed a wide knowledge base and a better range of alternatives. The chosen sample size was 21. The relevant research literature revealed that there is no fixed rule as to how many experts are required for the Delphi panel, nor is there an understanding on how much expertise or knowledge one needs to be chosen as an expert (Kaynak et al., 1994). Dalkey (1969) stresses that 15-20 members is the minimum number required. Ludwig (1997) agrees by stating that the majority of Delphi studies have consisted of 15 to 20 participants. It was also reported that the reliability of group responses increases as the size of the group increases: for instance, with a group size of 13, reliability with a correlation coefficient close to 0.9 was found (Dalkey et al., 1972).

Table 1 Selection of experts based on area of expertise in relation to the study

Area of expertise	Number of experts
Mechanisms of transfer (licensing executives, spin-off managers, venture capitalists)	5
Commercialisation officers (university commercialisation offices, legal experts, etc.)	6
Scientists and academics	5
Technology consultants	5

Generally, there is no interaction between the experts, decreasing any chance of bias. Experts also have some time to decide on their answers. Expert opinion is helpful as they are aware of the developments in their area and can therefore reliably contribute accurate information. Therefore, in this case, having a range of experts was useful in obtaining a clearer result (Ludwig, 1997; Ortt et al., 2006).

Based on the suggestions by Skulmoski et al. (2007), in relation to the design of the Delphi technique, below is a description of the altered and specific version of Delphi that was adopted for this research:

1. Mixed method approach, that is, qualitative and quantitative due to the fact that the experts were asked to rate as well as justify/comment on their choice.
2. The choice of experts was based on their knowledge, experience, and willingness to participate in and contribute to the research.
3. The number of participants chosen was 21. The recruiting of experts for the Delphi consisted of a simple yet efficient system, and snowball sampling was used in some cases.

Furthermore, the choice of experts was also based on their experience and area of expertise.

4. The mode of interaction with the experts was through online questionnaires and interviews. As Skulmoski et al. (2007) point out, the Delphi method can be used with a series of questionnaires to obtain and narrow down feedback from experts. It was decided that email would be used as the medium to send out the questionnaires for the Delphi rather than standard mail. This gave the participants more privacy, freedom, and time to answer at their leisure (Lindqvist & Nordanger, 2007).
5. The results were analysed using means, standard deviation, and inter-rater agreement (IRA), which will be discussed below.

In total two rounds of Delphi were conducted. The first round of Delphi consisted of six interviews and fifteen online questionnaires. The experts were requested to rate each criterion on a 5 point Likert scale, 1 being least important and 5 being very important. In this round, the experts were told to be as general as possible. The experts also had the opportunity to make any comments as well recommendations for the criteria if they felt something had been left out, while rating them so as to demonstrate their importance. It was assumed that the experts did not know who else had been approached even though snowball sampling was used in some cases, as they recommended several others and were unaware of those who agreed to participate. Some advantages using this technique are that no direct interaction is required and it is reliable as it helps to form opinions.

In the second round, each expert was contacted by email with instructions as to what needs to be done. The second round involved only the use of online questionnaires. Each expert was sent their previous results from round 1 as well as the mean of all results, and a breakdown of how many experts gave a particular rating for each criteria. The experts then had to study the information provided and decide whether they would like to remain on the same rating or change their results. The experts were informed that if they chose to maintain the same rating or change their rating that was considerably different from the mean, they were to justify why; whereas, if they chose to move closer to the mean or to the same number, this was not required. There was also room for additional comments if they wanted to add anything further.

The analysis included the calculation of the means as well as standard deviation. Furthermore, the inter-rater agreement (IRA) for the ratings of the experts was obtained using r_{WG} indices for both rounds of the Delphi. This was done as part of the analysis to investigate the agreement amongst experts in their rating, and to check if there was an emerging pattern of convergence, especially from the ratings in the second round as compared to the first. The r_{WG} index was calculated as follows:

$$r_{WG} = 1 - \frac{S_X^2}{\sigma_E^2}$$

where S = standard deviation and

$$\sigma_{EU}^2 = \frac{[(A]^2 - 1)}{\mathbf{12}}$$

where A is the scale adopted (for example 5 point or 7 point scale) (LeBreton & Senter, 2008).

The next section outlines and lists the selection of criteria that is used in the Delphi study.

4. Evaluation Criteria in Literature

As mentioned, firstly a general list was compiled from literature identifying the major categories of criteria that were essential for evaluation of a new technology. The important criteria under each respective category were also identified and listed. The experts were then asked to review this list by rating the criteria in the Delphi stages explained in the previous section.

Exhibit 1 consists of categories of criteria used to evaluate technologies for potential technology transfer and commercialisation. The criteria were obtained from different sources, for example, Durand (2003) reviewed ‘Key Technologies 2005’, a French technology foresight exercise which included criteria that were utilised to select candidate technologies. Rahal and Rabelo (2006) also identified and classified 43 determinants that are important in determining successful commercialisation and licensing of technologies from universities. One particular model of interest was the cloverleaf model developed by Heslop et al. (2001). This study aimed to identify the main constructs and criteria for the evaluation of technology through surveys. This model as well as some input from practitioners has largely influenced the chosen criteria. Heslop et al.’s (2001) study deal with obtaining evaluation criteria based on surveys, and suggests that better evaluated projects can lead to a more successful transfer. The study also originates from the fact that the different criteria involved, for example regulatory issues such as intellectual property (IP) and technological criteria related to the application of the technology, influence the choice of transfer and whether it is worth involving the technology in a new application. Heslop et al.’s (2001) research generally encompasses innovation literature such as adoption, and the creation of new applications and markets. The procedure involves choosing the criteria and then rating them according to which will help with assessment and evaluation.

As cited in Heslop et al. (2001), for an innovation to be successful, a combination of knowledge such as marketing and R & D is required. Entingh et al. (1987) also presented a set of criteria to help evaluate whether a technology is good enough to be transferred. In addition, Pelman (1998) suggests that the evaluation of technology and its transfer cannot be fully accurate unless experts and managers from industry contribute. Hence, this particular research is the only one that incorporates expert opinion through the recruitment of the Delphi technique.

The Cloverleaf Model consists of four categories, namely, market readiness, technology readiness, commercial readiness, and management readiness (Heslop et al., 2001). It uses three steps ranging from the initial compilation of a list criteria followed by a validation and then finally a refinement. The selection of criteria in this study is largely influenced by this model and other mentioned examples whereby a list of criteria is compiled from existing literature and then refined and validated through expert input.

The criteria listed Exhibit 1 is used for the Delphi method and structured so as to comply with transfers out of a university setting. Not all the criteria found in the literature have been used for the study as it was necessary only to include the core criteria found to be the most important and relevant to this study. This was achieved by omitting criteria that overlap and choosing criteria that would be best related to university commercialisation and suitable for the ex-ante stage. Therefore, some initial informal consultations with industry experts were conducted to confirm the choices.

Exhibit 1 List of criteria obtained from literature

1. Technological readiness:

Stage of development of the technology; Replicability possible; Technological Complexity (the nature and sophistication of the technology); Scope for alternate applications; Ready or Not (proof of concept) theory; Proof of application (in practice); Combinatory potential with other technologies; Prototype availability; Technical feasibility; Potential for further development; Newness of the technology (uniqueness)

2. Social benefits:

Knowledge spillover; Creation of employment; Enhancement of social infrastructure/networks; Environmental impact; Cost advantages to customers; Brand recognition; Potential for new useful applications

3. Economical and market factors:

Contribution to economic growth/development; Potential for attracting required resources for eg. venture capital; Potential return on investment; Market entry (pull/push); Distinguishable competitive advantages; Market impact; Level of Competition; Time to market

4. Legal and regulatory:

Protection of IP rights; Strengths and scope of patent including geographical extent; Patent exclusitivity; New areas of application (not infringing any other patents); Need for complimentary technologies (availability of licenses for example to use other technologies); Freedom to operate, for example, open innovation

Sources for criteria: Lee & Gaertner (1994); Arni (1996); Heslop et al. (2001); Dority (2003); Durand (2003); Roper et al. (2004); Reisman (2005); Rahal & Rabelo (2006); Schilling (2007)

5. Results of the Delphi Study

The two rounds of Delphi consisted mainly of online questionnaires with the 21 experts from four areas of expertise. The experts each had between 5 to 50 years experience in commercialisation and their positions included CEOs, professors, and investors amongst others. The rationale was to use experts with commercial experience who were employed in different areas so as to add variance and to investigate if each group of experts would answer differently.

Following both rounds, few recommendations for additional criteria were made including one that was considered important, namely, involvement of the inventor in the technology transfer process. Some experts spent more time discussing the criteria while a few were brief. While most of the criteria were rated important, there were some that belonged to the social factors category that were not considered as important. However, environmental impact and cost advantages were given an average borderline rating that has been considered. The initial interviews with six respondents helped by providing insight into the criteria used to rate a potential transfer. Overall, there was mostly a consensus amongst the experts, even in some of their recommendations. Statistical analyses comprised of means and standard deviations were then performed. Table 2 is a summary of the averages, standard deviations, and r_{WG} index of the ratings of criteria for both rounds along with the percentage differences of the averages and standard deviations.

It is useful to observe any major differences in the results obtained from the first and second round. The analysis between both rounds resulted in no major differences between the average ratings of criteria. The highest difference was an increase in the average rating for the criterion Market needs from 4.33 in the first round to 4.55 in the second round. This indicates that the experts were happy with most of their initial responses in round 1, and only a few made changes in the second round.

Table 2 Comparison of the averages and standard deviations of the ratings of criteria for both rounds along with percentage differences

Criteria	Round 1 Avg	Round 1 Stdev	Round 1 r_{WG}	Round 2 Avg	Round 2 Stdev	Round 2 r_{WG}	% Avg Dif.	% Stdev Dif.
1.Technological Readiness								
Stage of development of the technology	4.33	1.24	0.23	4.30	1.22	0.26	-0.67%	-0.40%
Replicability possible	4.10	1.00	0.50	4.25	0.55	0.85	3.10%	-8.90%
Technological Complexity (The nature and sophistication of the technology)	2.24	1.34	0.10	2.25	1.12	0.38	0.24%	-4.40%
Scope for alternate applications	3.30	0.86	0.63	3.20	0.83	0.65	-2.00%	-0.62%
Ready or Not (proof of concept in theory)	3.86	1.28	0.19	3.90	1.29	0.16	0.86%	0.35%
Proof of application (in practice)	3.76	1.26	0.20	3.95	1.05	0.45	3.76%	-4.22%
Combinatory potential with other technologies	2.71	1.01	0.49	2.70	0.98	0.52	-0.29%	-0.57%
Prototype availability	3.90	1.21	0.27	3.95	1.10	0.40	1.00%	-2.21%
Technical Feasibility	4.52	0.81	0.67	4.55	0.76	0.71	0.52%	-1.09%
Potential for further development	3.62	1.16	0.33	3.55	1.10	0.40	-1.38%	-1.24%
Newness of the technology (uniqueness)	4.00	1.10	0.40	4.00	0.97	0.53	0.00%	-2.44%
2. Economical and Market Factors								
Contribution to economic growth/ development	2.62	1.24	0.23	2.45	0.94	0.55	-3.38%	-5.99%
Potential for attracting required resources for example venture capital	4.62	0.67	0.78	4.70	0.66	0.78	1.62%	-0.24%
Potential return on investment	4.67	0.73	0.73	4.70	0.66	0.78	0.67%	-1.47%
Financial risk	3.74	1.10	0.40	3.70	1.03	0.47	-0.74%	-1.33%
Market needs (pull/push)	4.33	1.02	0.48	4.55	0.60	0.82	4.33%	-8.23%
Distinguishable competitive advantages	4.65	0.59	0.83	4.70	0.47	0.89	1.00%	-2.34%
Market impact	4.14	0.79	0.69	4.15	0.75	0.72	0.14%	-0.95%
Level of Competition	4.24	0.70	0.75	4.20	0.62	0.81	-0.76%	-1.70%
Time to market	4.24	1.00	0.50	4.30	0.86	0.63	1.24%	-2.61%
3. Social Benefits								
Knowledge spillover	2.33	1.20	0.28	2.25	1.12	0.38	-1.67%	-1.58%
Creation of employment	2.33	1.15	0.33	2.60	0.99	0.51	5.33%	-3.20%
Enhancement of Social infrastructure/networks	2.00	1.22	0.25	1.95	1.10	0.40	-1.00%	-2.51%
Environmental impact	3.05	1.28	0.18	3.05	1.15	0.34	0.05%	-2.75%
Cost advantages to customers/users	3.81	0.87	0.62	3.85	0.75	0.72	0.81%	-2.55%
Brand creation	2.90	1.22	0.25	2.85	1.04	0.46	-1.10%	-3.62%
Potential for new useful applications	3.48	1.21	0.27	3.42	0.96	0.54	-1.10%	-4.96%
4. Legal and Regulatory								
Protection of IP rights	4.33	1.02	0.48	4.35	0.88	0.62	0.33%	-2.83%
Strengths and scope of patent including geographical extent	4.29	1.10	0.39	4.35	0.93	0.56	1.29%	-3.37%
Patent exclusitivity	4.14	1.06	0.44	4.20	0.95	0.55	1.14%	-2.22%
New areas of application (not infringing any other patents)	3.90	1.00	0.50	4.10	0.55	0.85	3.90%	-8.85%
Need for complimentary technologies (availability of licenses for example to use other technologies)	3.76	1.04	0.45	3.80	0.95	0.55	0.76%	-1.86%
Freedom to operate, for example, open innovation	4.48	0.93	0.57	4.55	0.83	0.66	1.48%	-2.06%

In addition, inter-rater reliability (IRA) was also measured by calculating the r_{WG}index. A value of 0.70 is considered an acceptable number but this can vary depending on circumstances (LeBreton & Senter, 2008). Below are standards for interpreting IRA estimates as found in LeBreton and Senter (2008):

- .00 to .30 – Lack of agreement
- .31 to .50 – Weak agreement
- .51 to .70 – Moderate agreement
- .71 to .90 – Strong agreement
- .91 to 1.00 – Very strong agreement

Starting with the criteria, some did not have much difference in IRA levels between the two rounds. However, there was an increase in agreement in criteria as outlined in table 3.

Table 3 Increase in agreement for criteria in round 2

Criteria	r_{WG} Round 1	Agreement level in round 1	r_{WG} Round 2	Agreement level in round 2
Replicability possible	0.50	weak agreement	0.85	strong agreement
Technological complexity	0.10	lack of agreement	0.38	weak agreement
Proof of application (in practice)	0.20	lack of agreement	0.45	weak agreement
Prototype availability	0.27	lack of agreement	0.40	weak agreement
Newness of the technology	0.40	weak agreement	0.53	moderate agreement
Contribution to economic growth/development	0.23	lack of agreement	0.55	moderate agreement
Market needs	0.48	weak agreement	0.82	strong agreement
Time to market	0.50	weak agreement	0.63	moderate agreement
Knowledge spillover	0.28	lack of agreement	0.38	weak agreement
Creation of employment	0.33	weak agreement	0.51	moderate agreement
Enhancement of social infrastructure/networks	0.25	lack of agreement	0.40	weak agreement
Environmental impact	0.18	lack of agreement	0.34	weak agreement
Cost advantages to customers/users	0.62	moderate agreement	0.72	strong agreement
Brand creation	0.25	lack of agreement	0.46	weak agreement
Potential for new useful applications	0.27	lack of agreement	0.54	moderate agreement
Protection of IP rights	0.48	weak agreement	0.62	moderate agreement
Strength and scope of patent	0.39	weak agreement	0.56	moderate agreement
Patent exclusitivity	0.44	weak agreement	0.55	moderate agreement
New areas of application	0.50	moderate agreement	0.85	Strong agreement
Need for complimentary technologies	0.45	weak agreement	0.55	moderate agreement

Out of the 33 criteria, there was an increase in agreement in 20 of the criteria. After the second round, there were 10 criteria with strong agreement.

Overall, there was an increase in agreement for the criteria when looking at the IRA levels. Even though all criteria did not have a strong agreement, the majority had some level of agreement which is a good outcome following the Delphi. This is in turn is related to convergence of results which is necessary in a Delphi study, and consequently in the choice of criteria.

Generally, convergence was achieved after the second round. This is firstly indicated by very little difference in individual ratings of criteria and mechanisms between both rounds, and secondly, by the results based on standard deviation and IRA. For instance, the standard deviation after the second round was between and including 0.47 and 1.29 as compared to a range of and including 0.59 – 1.34 in the first round, indicating that there was an increase in agreement between experts and that the spread of responses was smaller after the second round of Delphi. Convergence is important as it implies that there is a level of agreement amongst experts.

It was then necessary to decide which criteria were deemed important and crucial and which ones would not be included in the final set of criteria. The guideline for the selection of criteria is based on averages of the results obtained from the Delphi. Any criteria with averages of 3 and above would be selected for the next round, because any criteria with an average below 3 is considered below-average and can thus be discarded, this has been verified by the experts as well. Along with the criteria selected according to the averages, any recommendations that were rated high by the experts and are considered important have been added to the list. As it happens, there are several that were common amongst most experts.

Totally, seven of the criteria were found to be below the average of 3, the criteria being:

- Technological complexity (2.25)
- Combinatory potential with other technologies (2.70)
- Contribution to economic growth/development (2.45)
- Knowledge spillover (2.25)
- Creation of employment (2.60)
- Enhancement of Social infrastructure/networks (1.95)
- Brand creation (2.85)

Some were very close to the average of 3, therefore, it was decided to consider the experts' comments for these criteria. Based on the comments, brand creation and creation of employment were noted to be important, therefore the others were dropped and are not included in the final list. Regarding the above criteria, the experts argued that they were not the key and core criteria used by them when evaluating a technology's commercial potential. But in the case of brand creation and creation of employment, after studying the comments from experts, it was learnt that potential for job creation and creating a brand or an entity for the technology early in the process could create better value. Additionally, based on experts' recommendations, one criterion, namely, involvement of the inventor was added because several experts recommended the same and rated it highly.

6. Discussion

As mentioned, Heslop et al. (2001) suggested four categories that can be useful in assessing the likelihood of a successful technology transfer or the early assessment of a technology, including: Market readiness, Technology readiness, Commercial readiness and Management readiness.

The outcome of this research suggests a similar set of categories and criteria, although the Management readiness category proposed by Heslop et al. is replaced by Social benefits and impacts in this study. The Social benefits category is an appropriate category, especially due to the recent importance of the environmental concern and the impact that technologies can have to the environment and other factors that influence society either directly or indirectly. Exhibit 2 is a collection of all criteria found to be important following the Delphi study.

The findings suggest that some of the highly-rated criteria were similar in importance to those obtained by Heslop et al. (2001) in their development of criteria that can be used to assess the readiness of technology. Criteria or readiness conditions as referred to by Heslop et al. (2001) were 54 in total and were ranked based on their ratings. For instance, 'distinct competitive advantage' was given a high rating with a mean of 4.70 on a five point scale in this study, and correspondingly was ranked second (out of 54) in Heslop et al's findings. Comparisons to exemplify similarities between both studies can be found in Table 4.

Exhibit 2 A collection of all criteria found to be important following the Delphi study

1.Technological Readiness	**3. Social Benefits & Impact**
Stage of development of the technology	Environmental impact
Replicability possible	Cost advantages to customers/users
Scope for alternate applications	Brand creation
Ready or Not (proof of concept in theory)	Potential for new useful applications
Proof of application (in practice)	Creation of employment
Involvement of inventor	
Prototype availability	
Technical feasibility	
Potential for further development	
Newness of the technology (uniqueness)	
2. Economical and Market Factors	**4. Legal and Regulatory**
Potential for attracting required resources, for example venture capital	Protection of IP rights
Potential return on investment	Strengths and scope of patent including geographical extent
Financial risk	Patent exclusitivity
Market needs (pull/push)	New areas of application (not infringing any other patents)
Distinguishable competitive advantages	Need for complimentary technologies (availability of licenses, for example to use other technologies)
	Freedom to operate, for example, open innovation
Market impact	
Level of Competition	
Time to market	

As Table 4 indicates, the importances of the corresponding criteria are similar in both studies. The table contains the averages obtained from the data collection with the ratings out of 5, as well as Heslop et al.'s findings (2001) with their ranking out of 54 (where 1 is highest). This demonstrates that the findings from the experts can be validated with the previous study.

Additionally, there was only one criterion, namely involvement of the inventor that was added through the Delphi. This is further justified in literature for the reason that unwillingness of the inventor(s) to participate in commercialisation can result in an unsuccessful outcome (MacBryde, 1997).

Table 4 Similarities in the types of criteria and their significance between results obtained though data collection and Heslop et al. (2001) findings

Transfer readiness conditions as suggested by Heslop et al. (2001)	**Rank (out of 54)**	**Criteria refined through the Delphi in this study**	**Average (out of 5)**
Distinct competitive advantages	2	Distinguishable competitive advantages	4.70
Expected positive Return On Investment (ROI)	5	Potential return on investment	4.70
Defined marketable product	6	Market needs (pull/push)	4.55
New, non-obvious invention	8	Newness of the technology (uniqueness)	4.00
Has future uses	9	Potential for further development and scope for alternate applications	3.55
No other dominant patents	10	Patent exclusivity	4.20
Inventor will champion	11	Involvement of inventor	Added due to experts' recommendation with importance
Immediate market uses	18	Time to market	4.30
Functioning prototype	36	Prototype availability	3.95

As this study has shown ex-ante assessment cover all major aspects related to technology transfer and commercialisation, from the technology itself to the potential markets it can have.

This is also emphasised by Thore (2002) who discusses the importance of the many aspects related to a technology and its commercialisation, such as the different factors that can influence whether a technology is ready to be commercialised and what factors could result in its success. This includes several dimensions such as aspects related to the readiness of the technology, the applications of a new technology, and what intellectual property the technology could generate. While some authors such as Luik (2005) recommended approaching evaluation based on specific factors such as market and economic related factors, others like Bellais and Guichard (2006) recommend using a combination of criteria all at once with an emphasis on intellectual property and market related criteria. Additionally, the question of which particular criteria or variables can help in assessing the success of commercialisation, can be justified by the choice of categories of criteria chosen for the evaluation as there is a general agreement in the literature about which dimensions of criteria including technology, environment, and the markets should be used by researchers (see Astebro, 2004; Heslop et al., 2001; Galbraith et al., 2007). In general this study shed light on the selection of a set of criteria that can be used as a prediction tool to determine those technologies that are most promising for a successful technology transfer from university inventions.

7. Concluding Remarks

The objectives of this paper relate to the ever-increasing involvement of universities in the commercialisation process. This only justifies the need for a better evaluation tool that can be used to assess innovation commercialisation and potential technology transfers from universities. Such a tool can be beneficial as it can aid in better decision making as well as the selection of the right technology, and the subsequent selection of the most favourable mechanisms for commercialisation. This article focussed on yielding a suitable approach for evaluating the potential for commercialisation of a new technology, by developing and compiling a list of the most important criteria used to evaluate the technology transfer process. More specifically, this study examined the ex-ante evaluation of the technology transfer process. To fulfil these objectives, criteria considered important for commercialisation according to the pertinent literature were accumulated, followed by the recruitment of experts with a range of expertise and commercialisation knowledge who gave their valuable input in refining these through the adoption of the Delphi technique, resulting in a more robust collection of criteria. Through the analysis of the collected data, the categories of criteria found to be important for ex-ante evaluation are: Technological Readiness, Legal and Regulatory, Social Benefits & Impacts and Economical and Market Factors.

Additionally this study has some practical implications, which may assist universities and industry in their evaluation procedures adopting the range of criteria resulting from this research. This will help in their decision making process when they are required to assess the usefulness and readiness of a technology for commercialisation and technology transfer purposes.

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