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Tools for Assessing Transfer-Worthiness of Technologies and Absorption & Innovation Capacities of Transferee Firms

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This paper is an outcome of the study of the transfer of spin-off technologies from a publicly funded nuclear research organization of India. The complex nature of nuclear technologies results in spin-offs that are technically advanced. However, it is prudent to assess upfront, the spin-off technology for its worthiness to be transferred to the industry as the success of tech-transfer depends on several factors additional to technical. By the same rationale, the firm aspiring to receive the technology needs to be assessed for its capacity to absorb it. Considering these two requirements, this paper first examines the conventional constructs such as the Technology Readiness Level and Absorptive Capacity (ACAP), expands them to suit the context, and develops the protocols for assessment. The methodology of research was both explorative and empirical. Literature was first examined to inform ourselves of the conceptual basis. The factors of the proposed constructs were initially drawn from the literature and then confirmed for relevance, with the experts in the field. The weights of relevance for the factors were also obtained from the experts. The assessment protocols of both constructs were formulated by the method of the *sum of the weighted factors*, to be compared with a pre-meditated threshold level. Thus, the paper's outcome is the assessment protocols, useful not only to the Technology Transfer Office (TTO) of the organization under study, but also extendable to other similar organizations.

Keywords: Management of technology, Public research organization, Technology readiness level (TRL), Technology transfer, Transfer worthiness level

Introduction

Public-funded Research Organizations (PROs), particularly the mission-oriented ones (PMROs) generate spin-off technologies (spin-offs, hereafter) along with the mandated technologies. Several spin-offs can have relevance to industries outside the mission. These are identified for transferring to the firms that take up the further stages of development for commercialization. Hence, unlike firm-to-firm transfers where the technologies are at commercial readiness, PRO-to-firm transfers have uncertainties in respect of commercial success.[1,2] To enhance the likelihood of commercial success of technology transfers (tech-transfers, hereafter) from PROs, it is prudent to first assess the technology for its readiness for a commercial venture. This calls for the development of a protocol for the assessment of the technology. On the other hand, the firm receiving the technology has to absorb the technology and successfully commercialize it. Hence, before undertaking the transfer of technology, it is prudent to first assess the aspiring firm's absorptive capacity.

Responding to both needs, the researchers first studied the relevant academic literature. Most of the literature corresponds to firm-to-firm tech-transfers rather than those of PMRO-to-firm. The research interest of the authors pertains to tech-transfers from a PMRO called Bhabha Atomic Research Centre (BARC) to which two of the researchers belong.

The traditional assessment constructs called Technology Readiness Level (TRL) and technology Absorptive Capacity (ACAP) respectively, are first examined. Noting an inadequacy in these constructs for the context under study, the authors conceptualize the expanded constructs called technology's Transfer-Worthiness Level (TWL) and firm's Absorption & Innovation Capacity (A&I-CAP) respectively. Further, the tools for their assessment are developed. The underlying research process is depicted in Fig. 1.

The next section reviews the literature on the subject. This is followed by a section on the methodology employed. Further, a section describes the need for expanding the traditional

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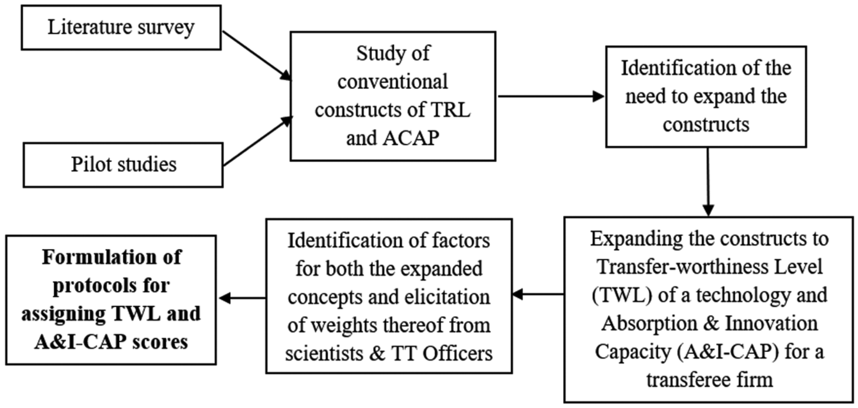

Fig. 1 — Research process underlying the development of the assessment tools

Table 1 — TRL assignments

Sl. No.	TRL No.	Meanings
1	TRL 1	Basic principles observed
2	TRL 2	Technology concept formulated
3	TRL 3	Experimental proof of concept
4	TRL 4	Technology validated in the laboratory
5	TRL 5	Technology validated in a relevant environment
6	TRL 6	Technology demonstrated in a relevant environment
7	TRL 7	Prototype demonstration in the operational environment
8	TRL 8	System complete and qualified
9	TRL 9	Actual system qualified in the operational environment

Source: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

assessment constructs. The subsequent sections show the formulation of both the assessment tools one by one. The paper ends with a discussion & conclusions.

Literature Review and Analysis

The conventional concept for assessing a technology is called Technology Readiness Level (TRL) introduced by NASA (The National Aeronautics and Space Administration of USA) during the 1970s as a figure of merit of the maturity in the developmental life cycle of a new technology, from the thought level to the product level in a 1-9 scale.[3] Later these levels were generalized to apply to technologies beyond space, as listed in Table 1).

This research based on a PMRO has informed that a scientist generally considers the technology to be ‘ready’ for transfer to industry if it functions reliably in the operational environment (TRL-7). Further development concerning manufacturability, ergonomics, and branding (say, TRL-8 and above) would be in the purview of the transferee firm.

Absorptive capacity (ACAP) is defined as the relative ability of an organization to (a) recognize the value of new technology, (b) acquire it, (b) assimilate it, (c) transform it and (d) apply it to economic ends[4,5], by a set of organizational routines and strategic processes, to create techno-economic value.[6]

In the early years of the proliferation of tech-transfer research, literature on industry-level technology absorption in international tech-transfers was generated. For example, Desai[7] focused on the industry-level absorption capacity in the Indian context.

Cohen & Levinthal[4] found that the accumulated prior knowledge increases both the ability to acquire new knowledge and also the ability to use it for commercial ends. They differentiated between staff-level absorptive capacities and firm-level absorptive capacities. They further stated the following.

1. Staff members with diverse backgrounds have a higher prospect of sensing that the incoming information would be usable for raising competitive advantage.
2. ACAP is the result of a firm’s R&D intensity (research expenditure per sales), manufacturing ability, training, and organizational culture.
3. An organization’s ACAP not only depends on the organization’s interface with the external

environment but also on transfers of knowledge across and within the organizational units.

4. Inward-looking ACAP is about consolidating and distributing the knowledge within the firm while outward-looking ACAP is about sourcing it from outside. Both are necessary.

5. Critical knowledge of a firm includes not only technical knowledge but also awareness of the sources of useful complementary expertise.

6. Some portion of internal knowledge shall be close to the external knowledge for easy assimilation and some portion shall be diverse to permit its commercial utilization.

7. The degree to which the firm captures the profits associated with its innovative capacity is higher if the knowledge developed does not easily spill over to other similar firms. Mechanisms for ensuring this include patents, confidentiality, hastening the learning curve, reduction of lead time, and uniqueness in complementary devices.

Zahra & George[5] opine that ACAP is a dynamic capability embedded in the firm's internal routines that makes it respond to change through managerial actions by suitably re-redeploying the firm's knowledge-based assets. The four dimensions of ACAP – acquisition, assimilation, transformation, and exploitation are grouped into two components namely - Potential Absorption Capacity (PACAP) and Realized Absorption Capacity (RACAP). PACAP is known for the ability to learn, whereas RACAP is known for the capacities of converting the available knowledge into business value. The ratio of RACAP and PACAP is called the efficiency factor of knowledge utilization.

Narasimhan *et al.*[8] state that marketing endeavors enhance the scanning for new technological options, giving rise to necessary triggers to acquire new knowledge. Noblet *et al.*[9] examined the concept of ACAP in terms of dynamic capacities, defined as the ability to integrate, build, and reconfigure internal and external competencies in response to changing environments.

Absorptive capacity was bifurcated into learning capacity and problem-solving capacity by Jae-Woong *et al.*[10] The latter part calls for innovation. Also, to ensure a better economic sense of tech-transfer, the firm has to bring out innovative products (services are included implicitly) through innovative processes.

Maldonado *et al.*[11] found, in their empirical studies, that ACAP is positively associated with a firm's technological innovation and financial performance.

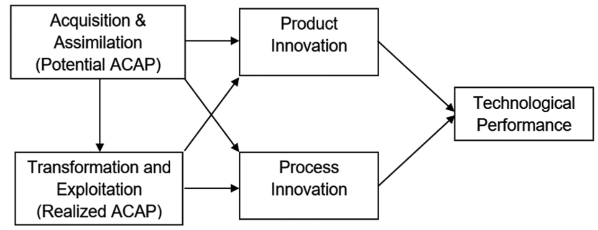

Fig. 2 — Model indicated by Zamora *et al.* (2021)[15]

Thus, innovation capacity has always been considered the most critical component of the competitive advantage of a firm in an increasingly changing environment.[12]

Innovation is defined as the adoption of an idea or behavior, about a new product or a new feature of a product, a service, a device, a system, a process, a new market, a policy, or a programme that is new to the adopting organization[13,14] and whose capacity is expressed in terms of product and process innovations[8], to acquire firm's competitive advantage by product innovation and/or the process-efficiency by process innovation respectively.[15]

Using the conceptualization of Cohen & Levinthal[4] and Zahra & George[5] , Zamora[15] combined the idea of two types of innovation, which gave a model for absorption and innovation capacities as shown in Fig. 2.

Methodology

The methodology is explorative and empirical, commencing with a literature review on the constructs TRL and ACAP separately. Then the rationale was built for expanding the constructs. The factors corresponding to each of the expanded constructs were identified by literature review. The literature largely pertains to commercial R&D organizations and universities rather than PMROs, which differ in several characteristics. For example, in the case of PMRO's technology, the mission-use could be different from the repurposed commercial use. But the end-use of a technology of a commercial R&D organization is usually well-defined. Another difference is that the scientist of a PMRO is relatively more concerned with the reliability of a technology rather than the cost & market considerations, Hence the factors were short-listed to suit the characteristics of a PMRO.

Considerations for choosing the protocol of quantitative assessment are as follows.

(a) The factors are largely independent of one another. Hence a linear combination of the factor-scores is a reasonable assessment of the construct in question.

(b) The factors can differ in relative importance in specific contexts, calling for the weights factor-scores. Hence the short-listed factors were then discussed with some 6 Nos. of relevantly experienced scientists and TT officers of BARC. During this discussion, they were also requested to assign weights (on a 7-point Likert scale) to each factor without specific reference to any technology or a transferee-firm.

(c) Based on above two points, the formula adopted in both the tools is 'the sum of weighted scores of the factors.'

(d) The assessment of this study is of the type 'single-entity, multiple factor'. The entity is either a technology or a transferee-firm. Hence there is no need for adopting other methods largely meant for multi-entity multicriteria decision methods such AHP (Analytic Hierarchical Process) that involves pair-wise comparison of multiple entities in terms of each factor.

Need for Expanding the Tradtional Constructs

The progress of development of technology through all TRLs is seamless in the mission technologies since all the stakeholders involved are connected with a common thread of the single end purpose. The end purpose resolves any mismatch in stakeholders' characteristics and results in smooth progress along the TRLs. This is illustrated with an example of the technology of mass spectrometers. When BARC commenced developing the technology, the proof of concept had already been established by the inventors abroad. Hence the starting point of BARC's scientists was TRL-4, i.e., technology validation in their laboratory. Subsequently, the scientists teamed up with electrical, electronics, and mechanical engineers to further develop the technology towards higher TRLs. When the scientists reached TRL-7, they started deploying the systems in various DAE units. However, the technological upgradation continued, and as many as 50 Nos. of mass spectrometers were deployed by developing the vendors for manufacturing. Thus, the progression across all TRLs took place seamlessly for internal deployments. The success of the mission was more important than any other factor such as economics or compactness. The internal users could handle technical difficulties with the ready availability of the developers of the system. However, when the technology is considered as a spin-off for external tech-transfer, factors additional to those included in TRL come into play. These are factors like manufacturing cost, attractiveness of design, ease of operation by individuals who might not be tech-savvy, after-sale service, etc.

The research has further found that each spin-off tech-transfer case has its own level notion of technology readiness for transfer.[16,17] Though the organization bringing forth a spin-off technology might consider the act of transfer itself as its primary objective, its secondary objective lies in enabling the transferee firm to achieve techno-economic success and to keep up its reputation. However, the techno-economic success of a transferred technology is contingent upon several factors in addition to TRL, (Heslop *et al*., 2001). Techno-economic success depends on several factors and hence there is a need to expand the construct, as described in the next section.

Similarly, the construct of ACAP was reexamined by considering certain technologies namely novel welding technologies[16] and rapid composting.[17] It was found that in addition to the ability to *absorb* the technology the firm should possess the ability to innovate, to make the received technology successful. Thus, it is considered appropriate to integrate the constructs of absorption and innovation capacities (A&I-CAP) to bring out a tool for assessing an aspiring tech transferee firm.

Development of the Tool for Assessing Technology Transfer-worthiness Level (TWL)

Heslop *et al.*[18] proposed a 4-parameter model) comprising technological readiness, management readiness, market readiness, and commercial readiness. According to Cooper[19,20] techno-economic success of a new commercial product has to be built at the development stage, the manufacturing stage, and the marketing stage. He listed the factors corresponding to each stage. The factors relevant to the research context are listed in Table 2.

Developing further on Heslop[18] and Cooper[19,20], the researchers conceptualize a construct called Transfer-worthiness Level (TWL). First, the factors were further short-listed by the researcher in the context of PMRO, and the weights were sought from the scientists and TT officers, by use of a questionnaire given in Table 3.

Responses to questionnaires were received and the weights for each factor were averaged. The weights were normalized by taking the ratio of each weight with the sum of all weights and multiplying by a calibration factor of 10. Sample calculations of normalization for first three factors are shown in Table 4, that lists factor weights and normalized factor-weights against each factor.

The factors listed in Table 4 are converted into questions as shown in Table 5 to add to the convenience in eliciting the factor weights.

Procedure Prescribed for Calculating TWL of a Technology

The assessment team may be constituted by TTO for evaluating the technology in terms of TWL. Members of the team shall assign scores (on a scale of

Table 2 — Relevant excerpted factors for making techno-economic success[20]

Factors about the developmental stage	Factors pertaining to the manufacturing stage
1. Innovative product, new to market	1. Product design is attractive in respect of appearance, ease of operation and ergonomics
2. The product has superior functionality	2. Product has a special feature that is absent in incumbent products
3. Preliminary assessment of the market is satisfactory	3. Manufacturing cost is reasonable
4. Lab prototype was satisfactory	4. Manufacturing design ensures fewer after-sales issues
5. Pilot production was satisfactory	5. Good fit for the firm's technological resources
6. Product cost likely to be lesser than an incumbent product	6. Adequate financial resources
7. Timing is appropriate for the end users	Factors pertaining to the marketing stage
8. End users' needs are clearly known	1. Incumbent firms are willing to take up the new version of the product
9. Government regulations are conducive	2. Market forecasting carried out
10. Preliminary costing is reasonable	3. Awareness of the structure of the market
11. Identified market pull	4. Equipped with market research
12. Strong technology push is ensured	
13. Prevalence of a champion	
14. Familiarity with mass-production technology	

Table 3 — Questionnaire for eliciting the weights of factors of TWL from experts

Sl. No.	Attribute / Factor	Least important factor: 1 Highly important: 7 1	2	3	4	5	6	7
	Technological factors							
1.1	Satisfactory functioning of the technology in the context of the mission for which the technology was developed.							
1.2	Safety concerns for exposure to radioactivity or any other hazardous material							
1.3	Scientists' knowledge about the requirements of end users.							
1.4	Ease of technology concerning absorption by a typical transferee-firm							
1.5	Ease of availability of necessary components and accessories							
	Market factors							
2.1	Awareness of scientists about the market for the end use of the technology							
2.2	Awareness of scientists about the market for the tech-transferees for the technology							
2.3	Possibility of the prototype-fabricator seeking the tech-transfer							
2.4	Advantages of the technology over competing technologies							
2.5	Export potential of the product of the technology							
	Commercial factors							
3.1	Possibility of generation of a new product by the technology							
3.2	Possession of unique selling points of the product created by the technology							
3.3	Estimation of the relevance of the technology for the current times							
3.4	Willingness of the scientist to champion success in pre and post transfer activities.							
3.5	Cost of the product of the technology, compared to competing technologies							
	Any other factors:							
1								
2								

Table 4 — List of averaged and normalized weights of the factors of TWL

Sl. No.	Factors	Factor-weights	Normalized factor weights
	Technological factors		
1.1	Satisfactory functioning of the technology in the context of the mission for which the technology was developed.	1	(1/12.35) × 10 = 0.81
1.2	Safety in respect of concerns for exposure to radioactivity or any other hazardous material	1	(1/12.35) × 10 = 0.81
1.3	Scientists' knowledge about the requirements of end users.	0.8	(0.8/12.35) × 10 = 0.65
1.4	Ease of technology with regard to absorption by a typical transferee-firm	0.85	0.69
1.5	Ease of availability of necessary components and accessories	0.6	0.48
	Market factors		
2.1	Awareness of scientists about the market for the end use of the technology	0.9	0.73
2.2	Awareness of scientists about the market for the tech-transferees for the technology	0.5	0.40
2.3	Possibility of the prototype-fabricator seeking the tech-transfer	0.6	0.49
2.4	Advantages of the technology over competing technologies	0.9	0.73
2.5	Export potential of the product of the technology	0.75	0.61
	Commercial factors		
3.1	Possibility of generation of a new product by the technology	0.9	0.73
3.2	Possession of unique selling points of the product created by the technology	0.9	0.73
3.3	Estimation of the relevance of the technology for the current times	0.7	0.57
3.4	Willingness of the scientist to champion success in pre and post transfer activities.	0.95	0.76
3.5	Cost of the product of the technology, compared to competing technologies	1	0.81
	Sum	12.35	10

Table 5 — Form for calculation of score of TWL for a technology to be assessed

Sl. No.	Factors	Score assigned (0 to 10) S_i	Normalized weight W_i	Weighted score $S_i \times W_i$
	Technological factors			
1.1	To what degree of satisfaction did the technology function well in the mission?	—	0.81	—
1.2	To what extent the technology is safe in respect of concerns of radioactivity or any other hazardous material?	—	0.81	—
1.3	To what confidence level, the needs of the end users are built into the technology?	—	0.65	—
1.4	To what confidence level, your technology is easy to absorb by a typical firm?	—	0.69	—
1.5	To what extent the complementary components are easy to obtain?	—	0.48	—
	Market factors			
2.1	What is your judgment on the market for the end users of your technology?	—	0.73	—
2.2	What is your judgment on the market for the tech-transfereesof your technology?	—	0.40	—
2.3	What is the likelihood that the fabricator of the prototype would be a formal tech-transferee?	—	0.49	—
2.4	To what extent your technology has distinct advantages over competing ones?	—	0.73	—
2.5	What is the export potential of the technology?	—	0.61	—
	Commercial factors			
3.1	What is the possibility that your technology would generate a new product inthe industry?	—	0.73	—
3.2	To what extent you are sure that the product of your technology has unique selling points?	—	0.73	—
3.3	To what extent is the technology for the current demand and not futuristic or out of date?	—	0.57	—

(*contd.*)

Table 5 — Form for calculation of score of TWL for a technology to be assessed (*contd.*)

Sl. No.	Factors	Score assigned (0 to 10) S_i	Normalized weight W_i	Weighted score $S_i \times W_i$
3.4	To what extent the scientist is willing to champion the technology till the success of transferee and for further development?	—	0.77	—
3.5	What is the likelihood that the product of your technology would be cost competitive?	—	0.80	—
	Total weighted score: Sum of all S_i x W_i			

Table 6 — Example calculation sheet for rapid composting technology

Sl. No.	Factors	Score assigned (0 to 10) S_i	Normalized weight W_i	Weighted score $S_i \times W_i$
	Technological factors			
1.1	To what degree of satisfaction did the technology function well in the mission or in your lab?	10	0.81	8.1
1.2	To what extent the technology is safe for concerns of radioactivity or any other hazardous materials?	10	0.81	8.1
1.3	To what confidence level, the needs of the end users are built into the technology?	9.5	0.65	6.17
1.4	To what confidence level, your technology is easy to absorb by a typical firm?	9.5	0.69	6.55
1.5	To what extent the complementary components are easy to obtain?	9	0.48	4.32
	Market factors			
2.1	What is your judgment on the market for the end users of your technology?	8	0.73	5.84
2.2	What is your judgment on the market for the tech-transferees for your technology?	8	0.40	3.2
2.3	What is the likelihood that the fabricator of the prototype would be a formal tech-transferee?	10	0.49	4.9
2.4	To what extent your technology has distinct advantages over competing ones?	9.5	0.73	6.93
2.5	What is the export potential of the technology?	7.5	0.61	4.58
	Commercial factors			
3.1	What is the possibility that your technology would generate a new product in the industry?	8	0.73	5.84
3.2	To what extent you are sure that the product of your technology has unique selling points?	10	0.73	7.3
3.3	To what extent is the technology for the current demand and not futuristic or out of date?	9.5	0.57	5.42
3.4	To what extent the scientist is willing to champion the technology till the success of the transferee and for further development?	8	0.77	6.16
3.5	What is the likelihood that the product of your technology would be cost-competitive?	8.5	0.80	6.8
			Total weighted score: Sum of all $S_i \times W_i$	90.21

1–10) based on their judgment for each question. Scores assigned by various individuals are averaged and entered into Table 5.

Each average score shall then be multiplied by the respective normalized weight to obtain the weighted score for each question (or factor). The sum of the weighted scores gives the overall score of the technology's TWL on the percentage scale. The assessment team may decide a minimum percentage above which the technology may be considered transfer-worthy.

An illustrative assessment is shown here by taking rapid composting technology as an example. The scores were assigned by the concerned scientist. The calculation is shown in Table 6.

The TWL score 90.2% of the rapid composting technology is considered very good.

A similar endeavor was carried out to develop the tool of assessment for A&ICAP of a transferee firm. This is explained in the following sections.

Development of the Tool for Assessing A&I-CAP of a Transferee Firm:

This study combines the concepts of absorptive capacity, innovative capacity, product innovation and

Table 7 — Differences between absorptive and innovative capacities for product and process developments

	Absorptive capacities	Innovative capacities
Product development	Knowledge of 'what' of the product to manufacture	Knowledge of 'what, how and why' of the product to manufacture
Process development	Knowledge of 'how' of the process of manufacture	Knowledge of 'what, how and why' of the process of manufacture

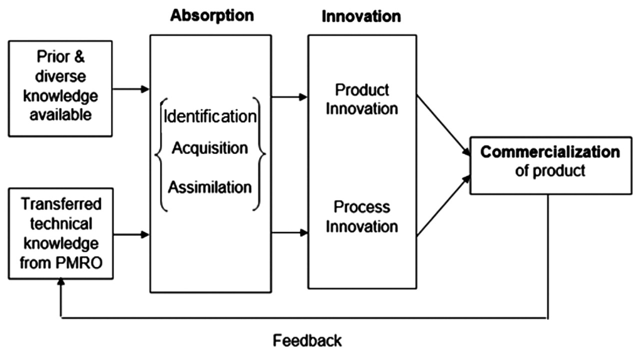

Fig. 3 — Conceptual model of A & I-CAP built by the authors

process innovation. An idea on how absorptive and innovation capacities differ for product and process development is outlined in Table 7.

Conceptual Model

Model development is an appropriate methodology to understand the relationship between the success attributes and the research environment.[21] The model offers a means, often in pictorial form in the case of the qualitative domain, to identify and structure the closely related attributes to synthesize a multidimensional construct. Hence, as a preparatory step to develop the tool, the researchers formulate a model for the construct A&I-CAP (Fig. 3), appropriate to the context, by building upon Zamora.[15]

The model is briefly explained as follows. Every firm has prior knowledge. More of it and its diversity is useful for the absorption of new knowledge. Prior knowledge helps to identify useful external technical knowledge for an internal purpose. Tech-transfer is one method for acquiring external knowledge. The acquisition of the identified knowledge needs prior knowledge and requisite managerial abilities. Further, the prior knowledge helps in assimilating the new knowledge. The assimilated knowledge has now to be transformed into a profitable product or service, using the skills of product and process innovations. Availability of diverse knowledge is an important prerequisite for germinating an innovation. Once an innovative product has been developed, the firm has to invoke all necessary managerial processes to make it a commercial success. The model thus represents the amalgamation of requisite attributes in absorbing and innovating the transferred technical knowledge from a PMRO, for effective commercialization. The model constitutes the following dimensions of A&I-CAP of transferee firms: Identification of appropriate technology, its acquisition, its assimilation, the prior knowledge, diverse knowledge, process innovation, product innovation and commercialization process.

The factors of assessment are associated with the dimensions constituting the model. While dimensions were drawn from the model, the factors were selected from the literature, as listed in Table 8.

Confirmation of Factors and Elicitation of Weights of Importance Thereof

Some experts (scientists and tech-transfer officers) were consulted to confirm the applicability of the factors. An exercise similar to what was done for the TWL was undertaken.

Out of 26 factors listed in Table 7, certain factors of a similar nature were combined. For example, the first two factors were combined to form a single factor of motivation. Certain factors that were considered unimportant by the experts were discarded. For example, firm size is not felt important since sub-contracting certain jobs is always possible. Also, the availability of a physical library is not considered important. Accordingly, a set of 21 factors were finalized. The values of average and normalized weights thus obtained are listed in Table 9.

Procedure Prescribed for Calculating A&I-CAP of a Transferee Firm

The assessment team may interview the transferee firm and may assign the scores against each factor, on a scale of 1 to 10. These may be filled in the form shown in Table 10.

Each score may be multiplied with the respective normalized weight to obtain a weighted score for each factor. The sum of the weighted scores of all factors gives the overall score of the firm's A&I-CAP. The assessment team may decide a minimum percentage above which the aspiring firm may be selected for transferring the technology.

An example calculation is shown in Table 11 with scores assigned by the stakeholders to a transferee firm that sought rapid composting technology.

Table 8 — Factors for assessment of transferee firm under each dimension identified by the authors (Fig. 3)

Sl. No.	Factors of each dimension	Source	Dimension
1	Motivation from a business angle	Researcher's insight	Identification
2	Motivation from a technology angle		
3	Awareness of evolving technologies		
4	Experience in receiving a tech-transfer	Researcher's insight	Acquisition
5	Prevalence of needed technical infrastructure		
6	Willingness to spend on R&D	9	Assimilation
7	Qualifications of the staff	Researcher's insight	
8	Availability of library		
9	Availability/access of laboratory		
10	Prior knowledge related to the products/services	5	Prior knowledge
11	Experience in similar/allied technologies	4	
12	Availability of manpower with diverse knowledge areas	4	Diverse knowledge
13	Experience in creative problem-solving	Researcher's insight	Process innovation
14	Marketing expenditure per sales	9	
15	Experience in process innovation	8	
16	Proportion of technical personnel over total strength	6	
17	Existence of advanced equipment	Researcher's insight	
18	Firm size		
19	Prior stock of product innovation	9	Product innovation
20	Manufacturing ability	Researcher's insight	
21	Experience in building high-tech products		
22	Whether launched any product that was the first in the market?	22	
23	Experience in cost-accounting	Researcher's insight	Commercialization of product
24	Experience in launching novel products		
25	Network with suppliers of complementary devices		
26	Export propensity		

Table 9 — List of average and normalized weights of the factors elicited from experts

Sl. No.	Factors for assessment of tech-transferee's capacities in absorption & innovation	Average weight assigned	Normalized weight
1	Strength of motivation to take technology	0.86	0.57
2	Awareness of evolving technologies	0.7	0.47
3	Experience in receiving a tech-transfer	0.7	0.47
4	Prevalence of needed technical infrastructure	0.91	0.62
5	Willingness to spend on R&D	0.8	0.53
6	Senior staff being qualified	0.65	0.43
7	Practical skill-set of the staff	0.81	0.54
8	Availability/access of laboratory	0.75	0.5
9	Prior knowledge related to the products/services	0.86	0.58
10	Experience in similar/allied technologies	0.8	0.53
11	Availability of manpower with diverse knowledge areas	0.8	0.53
12	Experience in creative problem-solving	0.5	0.33
13	Marketing expenditure per sales	0.85	0.57
14	Proportion of technical personnel over total strength	0.5	0.33
15	Manufacturing ability	0.65	0.43
16	Experience in product innovation	0.4	0.26
17	Experience in process innovation	0.5	0.33

(*contd..*)

Table 9 — List of average and normalized weights of the factors elicited from experts (*contd.*)

Sl. No.	Factors for assessment of tech-transferee's capacities in absorption & innovation	Average weight assigned	Normalized weight
18	Experience in building high-tech products	0.8	0.53
19	Experience in cost-accounting	0.3	0.33
20	Network with suppliers of complementary devices	0.9	0.61
21	Export propensity	0.76	0.51
	Sum of normalized factor weights	—	10

Table 10 — Form for assessing the aspiring tech-transferee firm

Sl. No.	Factors for assessment of tech-transferee's capacities in absorption & innovation	Score assigned (0 to 10)	Normalized weight	Weighted score
1	Strength of motivation to take technology	—	0.57	—
2	Awareness of evolving technologies	—	0.47	—
3	Experience in receiving a tech-transfer	—	0.47	—
4	Prevalence of needed technical infrastructure	—	0.62	—
5	Willingness to spend on R&D	—	0.53	—
6	Senior staff being qualified	—	0.43	—
7	Practical skill-set of the staff	—	0.54	—
8	Availability/access to laboratory	—	0.5	—
9	Prior knowledge related to the products/services	—	0.58	—
10	Experience in similar/allied technologies	—	0.53	—
11	Availability of manpower with diverse knowledge areas	—	0.53	—
12	Experience in creative problem-solving	—	0.33	—
13	Marketing expenditure per sales	—	0.57	—
14	Proportion of technical personnel over total strength	—	0.33	—
15	Manufacturing ability	—	0.43	—
16	Experience of product innovation	—	0.26	—
17	Experience of process innovation	—	0.33	—
18	Experience in building high-tech products	—	0.53	—
19	Experience in cost-accounting	—	0.33	—
20	Network with suppliers of complementary devices	—	0.61	—
21	Export propensity	—	0.51	—

Table 11 — Example assessment for a transferee firm for rapid composting technology

Sl. No.	Factors for assessment of tech-transferee's capacities in absorption & innovation	Score assigned (0 to 10)	Normalized weight	Weighted score
1	Strength of motivation to take technology	7	0.57	3.99
2	Awareness of evolving technologies	8	0.47	3.76
3	Experience in receiving a tech-transfer	4	0.47	1.88
4	Prevalence of needed technical infrastructure	6	0.62	3.72
5	Willingness to spend on R&D	5	0.53	2.65
6	Senior staff being qualified	7	0.43	3.01
7	Practical skill-set of the staff	9	0.54	4.86
8	Availability / access of laboratory	5	0.5	2.5
9	Prior knowledge related to the products/services	6	0.58	3.48
10	Experience in similar/allied technologies	7	0.53	3.71
11	Availability of manpower with diverse knowledge areas	4	0.53	2.12
12	Experience in creative problem solving	6	0.33	1.98
13	Marketing expenditure per sales	7	0.57	3.99

(contd.)

Table 11 — Example assessment for a transferee firm for rapid composting technology (*contd.*)

Sl. No.	Factors for assessment of tech-transferee's capacities in absorption & innovation	Score assigned (0 to 10)	Normalized weight	Weighted score
14	Proportion of technical personnel over total strength	8	0.33	2.64
15	Manufacturing ability	3	0.43	1.29
16	Experience in product innovation	8	0.26	2.08
17	Experience in process innovation	7	0.33	2.31
18	Experience in building high-tech products	3	0.53	1.59
19	Experience in cost-accounting	5	0.33	1.65
20	Network with suppliers of complementary devices	8	0.61	4.88
21	Export propensity	6	0.51	3.06
				61.15

The score of the example tech-transferee firm is 61.15%. Assuming that the assessment team had set a minimum score of 50%, this firm may be considered to have an adequate level of A&I-CAP to proceed with tech-transfer.

Conclusions

Spin-off technologies transferred from PROs though technically advanced, may not be easy to make an economic success when transferred to industrial firms. The conventional constructs TRL and ACAP are not sufficient, and hence, we have conceptualized the expanded constructs namely technology's transfer worthiness level (TWL) and aspiring firm's absorption & innovation capacity (A&I-CAP).

Both constructs, i.e., TWL and A&ICAP are conceptualized based on literature and reflection of the authors. A lists of determining factors were first selected from the literature and verified by the experts. The weights of importance of the factors were also elicited from the experts. The proposed assessment is made by taking the sum of weighted factor-scores assigned to the technology or the transferee firm as the case may be, and is then compared with a pre-meditated threshold value for making a decision.

The authors did not face any limitations in performing this research to fulfil the objectives set for themselves. The protocols proposed are usable by the scientists and TT experts of the organization of the study. However, acknowledging the dynamic nature of techno-economics, the weights of the factors for both may be updated periodically in future. Other similar organizations can develop such tools by similar method, with the factors specific to their systems.

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