Management of Technology Transfer from Indian Publicly Funded R&D Institutions to Industry-Modeling of Factors Impacting Successful Technology Transfer

H. Purushotham, V. Sridhar, and Ch. Shyam Sunder

***Abstract*—The major objective of this research was identifying and modeling of factors impacting successful technology transfer from Indian publicly funded R&D institutions to industry. Through a content analysis 27 variables have been identified, which are likely to impact a successful technology transfer. A conceptual technology transfer (TT) model and the hypotheses in terms of the identified variables were formulated. Through a questionnaire survey we have obtained the perceptions of 734 respondents from the concerned stakeholders on the relevance and importance of 27 variables in achieving successful technology transfer. The survey data was analyzed using factor analysis and regression analysis. The results of the empirical studies not only confirmed the conceptual model consisted of five TT facilitating factors and one outcome factor of successful technology transfer but also identified 10 critical variables that the stakeholders need to manage to achieve successful technology transfer.**

***Index Terms*—Technology transfer, conceptual model, publicly funded R&D institutions, critical success factors, India.**

I. Introduction

The importance of technology transfer (TT) for the well being of national economy, inter alia, national and international competitiveness, corporate profitability and growth has been well established and documented. In spite of the several pro-active policy initiatives, many of the technologies developed in Indian publicly funded R&D institutions have either remained unexploited or the desired impact has not been made by the transferred technologies, albeit a beginning has been made in a modest way [1]. Technology transfer is a lengthy, complex and dynamic process, whose success is impacted by various factors originating from different stakeholders. There is a strong need for identifying these factors and their contribution in achieving successful technology transfer so that stakeholders of the technology transfer can understand and manage the TT process effectively.

Numerous researchers have studied the factors affecting technology transfer and developed wide range of TT models. However, most of these models were related to international technology transfer from multinational corporations (MNCs) to local firms. Moreover, very few TT models were reported in literature that discusses TT from government laboratories and universities to industry and most of them were from a developed country's perspective. A recent seminal review on technology transfer from government laboratories to industry, concluded that academic research on the subject is much lesser in number and topic variety in the related academic journals as the field has just emerged in the mid 1980's due to the changes in government policy and hence has not yet attracted enough attention and interest of the research community [2]. The author is not aware of any comprehensive model developed under Indian context. It has been established that technology transfer is highly contextual and contingent in nature, and there is a need to identify the factors and build models as per the local conditions [3]. Therefore, this study attempts to identify and model the various factors that influence the successful technology transfer from publicly funded R&D institutions to industry under Indian context.

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H. Purushotham is with Center for Knowledge Management of Nanoscience and Technology, ARCI- Hyderabad, India (email:h.purushotham@gmail.com).

V. Sridhar is with IBS, Hyderabad, India.

Ch. Shaym Sunder was with Dept. of Commerce and Business Management, Osmania University, Hyderabad, India.

II. Literature Review

A literature review was undertaken, with the help of online database, i.e; Web of Science, the world's most popular and frequently used global database of choice for broad review of scientific accomplishment in all fields of study [4]. Researchers have offered many TT models and methodologies since the early 1970s. About 148 qualitative and quantitative TT models were reported in the literature during the period 1991-2012. Through content analysis of the published literature, 27 variables which are likely to influence or impact the success of technology transfer from publicly funded R&D institutions to industry have been identified. All these 27 variables were hypothetically grouped by conceptualizing their relationship with one another in the above context into five broad exogenous/ input /facilitating factors (constructs); i.e. (i) technology transferor factor (ii) technology receiver factor (iii) market factor (iv) finance factor (v) government factor and one endogenous/output factor (construct), i.e. successful technology transfer.

The literature reinforcement for including each of the 27 variables in the above mentioned factors are summarized as under. 'Technology transferor factor' concerns about the strength of technology in terms of six variables such as intellectual property rights [5]-[8], field tested prototype [1], [5], [9], exclusive licensing [6], [10], [11], training and demonstration [9], [12], performance guarantee [9], [13] and effective communication [13]-[15]. 'Technology receiver factor' deals with the adoption /absorption capability of the

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technology receiver particularly in terms of variables such as top management championing the project [5], [16], [17], having competent team [5], [13], strong financial background [1], [16], [18], prior business experience [1], [15], [19], vision and passion [19] and domain knowledge [8], [19]. 'Market factor' primarily addresses the market potential for the product/service in terms of variables such as large market size [6], [19], [20], product meeting user needs [5], [18], [19], product/service having competitive price and quality [5], [6] and first to market [5], [19]. 'Financial factor' concerns with the variables such as techno-economic feasibility / variability [9], [21], [22], easy access to finance [1], [5], [9], [20] and longer repayment period of debt [1]. 'Government policy factor' concerns with the variables such as pro-active legislative acts [7], [20], [23]; financial incentives from government [1], [24] and strengthening of the existing financial/incubation schemes [1], [24], [25]. 'Successful technology transfer factor' concerns the individual entrepreneur/company satisfaction on the envisaged outcomes of the implemented technology transfer project in terms of variables such as commencement of commercial production [26], launch of product in the market [16], [20], [26], attractive return on investment [1], [27], [28] and socio economic development [3], [22], [28]. Table I presents summary of the factors and their associated variables along with factor analysis results.

III. Development of Conceptual Model

Development of a conceptual model for technology transfer aims to capture all the relevant measured variables/factors that influence the effectiveness of the TT process and the resulting transfer success. Based on the earlier models [3], [5], [20], we have developed a comprehensive conceptual model of technology transfer using the above mentioned five exogenous factors/constructs and one endogenous factor/construct i.e. successful technology transfer from publicly funded R&D institutions to the industry as shown in Fig. 1. The links between the exogenous factors and endogenous factor in the conceptual model have been largely conceptualized based on literature support and from an understanding of the technology transfer process from public funded R&D laboratories to industry. This conceptual model is in line with the research directions suggested by the current researchers in the field that there is a need for models developed based on factors that influence or affect technology transfer which will have better power to predict TT outcomes [20], [26]. Along with technology transferor and technology receiver factors, the model also takes into consideration marketing, financial and government policy factors as these factors were not considered in the previous models [26].

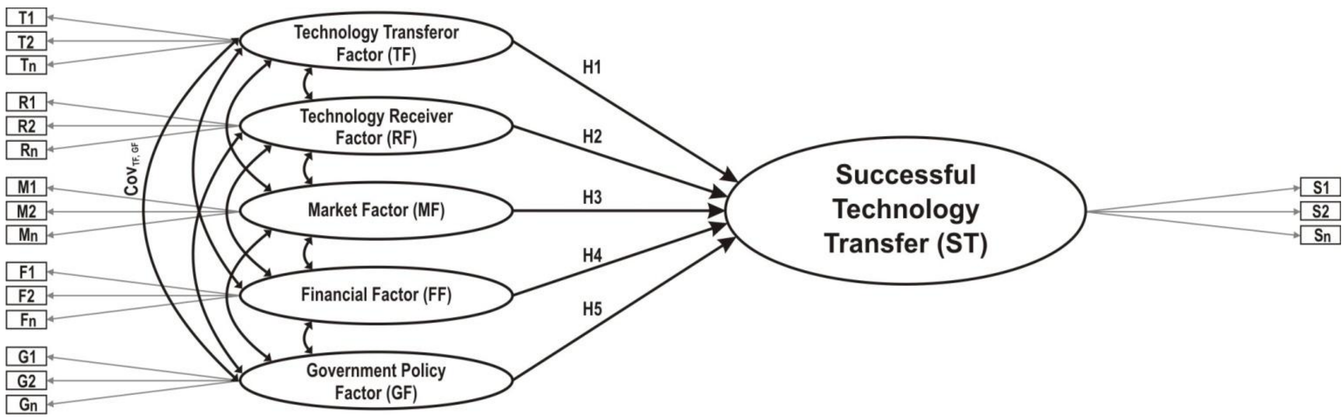

Fig. 1. Conceptual model for successful TT from publicly funded R&D institutions to the industry.

The relationship between the above mentioned factors or constructs along with their related measured indicators/variables is represented by five hypotheses as described below:

H1: Fulfilling technology transferor factor is considered as a key for successful technology transfer.

H2: Fulfilling technology receiver factor is considered as a key for successful technology transfer.

H3: Fulfilling market factor is considered as a key for successful technology transfer.

H4: Fulfilling finance factor is considered as a key for successful technology transfer.

H5: Enabling government policy is considered as a key for successful technology transfer.

The key variables likely to influence successful technology transfer as derived from previous studies as well as the hypotheses developed here constitute the foundation of the research model for this study. In this respect, a questionnaire using 5 point Likert scale was developed and each indicator or variable was presented as separate hypothesis to test its influence on successful technology transfer from public funded R&D laboratories to industry in India.

IV. Research Method

Since the overall research objectives of this study were to identify the factors influencing technology transfer, develop a conceptual model for TT in terms of these influential factors from public funded R&D laboratories to industry and examine the contribution of these factors on the success of technology transfer, technology transfer project itself is the level or unit of analysis. The respondents for data collection were chosen from public funded R&D institutions, technology financing institutions and private sector companies, which have in-house R&D units recognized by the Department of Scientific & Industrial Research (DSIR) and listed in the "Directory of R&D Institutions 2010" published by the Department of Science & Technology, Government of India. The Directory listed 4288 such institutions. Thus, respondents from the above population/universe were considered to be the best respondents to evaluate the importance and effectiveness of variables pertaining to the TT process and the outcomes it can potentially generate.

To measure the perceptions of the respondents on the identified 27 variables, which are likely to be influencing the success of technology transfer, we have developed a survey instrument primarily on the basis of the survey questionnaires reported in the literature [5], [20], with a few modifications to suit the research purpose and particular study context. The survey questionnaire contained three sections. Section 1 covers demographic information of the respondents such as name, gender, organization name, age, years of experience in technology transfer, position, education, organization type (publicly funded R&D institution or private company) etc. This section was included to ensure that information was received from valid sources. Section 2 covers total of 27 questions representing individual variables in the conceptual model. Section 3 seeks suggestions to improve the technology transfer. The responses/suggestions provided were used to supplement the quantitative analysis. On the pilot tested questionnaire, respondents were asked to evaluate the importance of each variable on a 5-point Likert scale (1= strongly disagree, 5=strongly agree). Five-point Likert scale was used instead of 7-point scale since it is reported that the respondents have a tendency to avoid the two extreme points. This tendency makes 7-point scale less applicable in social science research settings [29].

The questionnaire survey was undertaken during May-August 2012 with the above target group of respondents. Out of 3000 questionnaires administered (based on purposive sampling), 806 filled in questionnaires were received after substantial follow-up. 72 filled questionnaires were rejected as the respondents were not having the minimum qualifying experience of associating with at least one technology transfer project at the time of filling the questionnaire. The balance 734 filled in questionnaires, representing a response rate of 24. 5 per cent, which exceeds the minimum 1:5 ratio requirement (questions: responses) for factor analysis [30] were taken up for statistical analysis.

V. Data Analysis and Results

The collected data was analyzed, using the statistical package for the social sciences (SPSS v16) in which the Cronbach's alpha, means and standard deviations (S.D), analysis of variance (ANOVA), and exploratory factor analysis (EFA) were performed. Regression analysis was used to test the hypotheses and the conceptual model.

A. Respondents Profile

Respondents were classified into six categories: scientists (25%), technology transfer professionals (15%), technology financing professionals (5%), professors (10%), R&D managers from industry (25%) and directors/chief executive officers/managing directors/chairman (20%). The respondents' level of education was classified into three levels: bachelor's degree (16%), master's degree (34%) and PhD degree (50%). Age of respondents was also noted: under 40 years (5%), 40-50 years (21%), 51-60 years (63%), and over 60 years (11%). Number of TT projects coordinated by the respondents was also sought. 86% of the respondents coordinated 1-5 TT projects, 11% coordinated 6-10 projects and 3% of the respondents coordinated more than 10 TT projects. The breakup of respondents' technology transfer experience was, less than 10 years (22%), 10-20 years (54%), 21-30 years (20%), and over 30 years (4%). The respondents' areas of technology transfer experience include chemical sector (30%), drugs & bio-pharma (34%), materials and nanotechnology (14%), food and agriculture (10%), electronics (5%), telecommunications (4%) and information technology/ information technology enabled services (3%). The respondents were from either publicly funded R&D institutions (55%) or private sector (45%). The respondents were from across the country: southern region (41%), northern region (20%), eastern region (10%) and western region (29%).

ANOVA was performed to ensure that respondents of different age, education level, positions, length of experience, and type of organizations could be considered as a single sample. ANOVA confirmed congeners between these variables at the 0. 05 level of significance [31].

The personal profiles of the survey respondents show that the participants are fairly senior, predominantly technical oriented persons having experience in diverse areas of technology development and transfer. Experience of participants from wide range of technology verticals was critical for ensuring the validity of results. The greater is the experience of respondent in technology development and transfer, greater will be their understanding of the issues involved in the technology transfer.

B. Mean and Standard Deviation

The mean and standard deviation for each variable and the overall construct were computed. Among all the five facilitating factors/constructs, finance factor/construct was ranked the highest overall mean value (Mean = 4.47, S.D = 0.83) followed by market factor (Mean = 4.36, S.D = 0.69), technology transferor factor (Mean = 4.35, S.D = 0.82), government policy factor (Mean = 4.07, S.D = 0.83) and technology receiver construct (Mean = 4.05, S.D =0.85). It may further be noted that among all the 27 variables examined in this study, the variable having large market size was ranked the highest mean (Mean = 4.75, S.D =0.56). The preliminary survey analysis results show that financial, market and technology transferor factors play a dominant role in facilitating successful technology transfer from public funded R&D institutions to industry. Most of the TT outcome variables were found highly and equally important. Respondents perceived that commencement of commercial production (Mean = 4.23, S.D = 1.13) within the planned schedule was the most important variable followed by the launch of product/service (Mean = 4.20, S.D = 1.05), as achieving these two near term outcomes are precursors for reaping the remaining long term benefits of the successful technology transfer project.

The results further show that high mean values (more than the midpoint of Lickert scale, i.e. >3) and lower standard deviations of all the factors, suggesting that (i) respondents had similar perceptions about variables within the constructs and they were all very important, (ii) the variables identified in each construct were accurate in describing the influential factors of the TT process and (iii) all respondents clearly understood the responses required of them.

In general, all the 27 evaluation variables have a mean rating higher than three (i.e. above the midpoint along the 5-point Likert scale) indicating that they are important and critical to the successful technology transfer [7]. Therefore, all the 27 variables were utilized for the subsequent factor analysis. Table I includes mean and standard deviation of the variables studied and Fig. 2 presents the top 10 critical variables identified by the survey respondents.

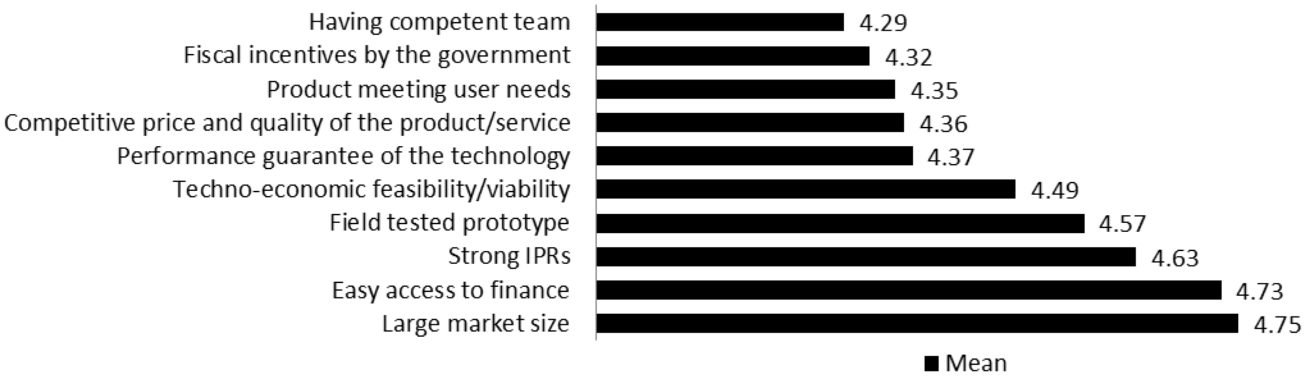

Fig. 2. Top 10 critical variables identified by survey respondents.

TABLE I: VARIMAX ROTATED FACTOR LOADING FOR THE FINAL SIX-FACTOR SOLUTION

Factor/Construct	Code	Measurement variables	Factor loading	Mean	Standard Deviation (S. D)
1. Technology transferor factor	T1	Strong IPRs	0. 804	4. 63	0. 64
Variance = 18. 4%	T2	Prototype field tested	0. 905	4. 57	0. 58
Eigen value= 4. 78	T3	Exclusive Licensing	0. 855	4. 19	1. 05
Cronbach's Alpha= 0. 94	T4	Training & Demonstrated	0. 870	4. 24	0. 91
Overall construct mean : 4.35 (S.D: 0.82)	T5	Performance guarantee	0. 883	4. 37	0. 78
	T6	Effective communication	0. 909	4. 09	0. 97
2. Technology receiver factor	R1	Top management champions the project	0. 744	3. 95	1. 11
Variance = 13. 32%	R2	Having competent team	0. 523	4. 29	0. 98
Eigen value= 3. 46	R3	Strong financial background	0. 598	4. 17	1. 08
Cronbach's Alpha= 0. 712	R4	Prior business experience	0. 555	3. 96	0. 78
Overall construct mean : 4.07 (S.D: 0.85)	R5	Vision & Passion	0. 583	3. 98	0. 62
	R6	Marketing capability	0.601	4.23	0.89
3. Market factor	M1	Large market size	0. 845	4. 75	0. 56
Variance = 8. 8%	M2	Product meeting user needs	0. 666	4. 35	0. 81
Eigen value= 2. 29	M3	Competitive price and quality	0. 859	4. 36	0. 71
Cronbach's Alpha= 0. 708					
Overall construct mean : 4.49 (S.D: 0.69)					
4. Finance factor	F1	Techno-economic feasibility/ variability	0. 692	4. 49	0. 82
Variance = 8. 8%	F2	Easy access to finance	0. 822	4. 73	0. 68
Eigen value= 2. 28	F3	Longer repayment period of debt	0. 661	4. 18	1. 00
Cronbach's Alpha= 0. 709					
Overall construct mean : 4.47 (S.D: 0.83)					
5. Government influence factor	G1	Proactive legislative acts	0. 924	3. 93	1. 23
Variance = 8. 7%	G2	Fiscal incentives	0. 871	4. 32	0. 86
Eigen value= 2. 26	G3	Strengthening the existing technology financing schemes	0. 770	3. 98	0. 42
Cronbach's Alpha= 0. 830					
Overall construct mean : 4.07 (S.D: 0.83)					
6. Successful transfer outcomes	S1	Commencement of commercial production	0. 771	4. 23	1. 13
Variance = 7. 5%	S2	Launch of product in the market	0. 805	4. 20	1. 05
Eigen value= 1. 93					
Cronbach's Alpha= 0. 856	S3	Attractive Return on Investment	0. 777	4. 12	1. 08
Overall construct mean : 4.12 (S.D: 1.13)	S4	Socio-economic development	0. 731	3. 93	1. 24

C. Factor Analysis

The data sample was deemed adequate for factor analysis, as the responses to variables ratio exceeded 5:1 [30]. Moreover, the value for the Kaiser-Meyeer-Olkin (KMO) measure of sampling adequacy was 0.811, which exceeds the recommended threshold level of 0.50 [32]. Exploratory principal component factor analysis (EFA) with varimax rotation was conducted using SPSS package to condense the information contained in the original 27 variables into a smaller set of factors with a minimum loss of information [30]. The SPSS-EFA retained 24 variables and extracted a six (6) factors solution best representing the data, accounting for 65.4% of the total variance. They were labeled as five input or enabling factors, viz; (1) technology transferor factor with six variables; (2) technology transferee/receiver factor with five variables; (3) market factor with three variables (4) financial factor with three variables; (5) government influence factor with three variables and (6) one outcome factor, i.e. successful technology transfer with four variables. A total of 24 variables out of 27 variables studied were loaded properly on the six factors. Two variables, namely: first to market and domain knowledge of the technology receiver have been deleted as they were having a factor loading of less than the threshold factor loading of 0.50 [30]. The remaining 24 factors were having the acceptable factor loadings ranging from 0.523 to 0.924. A Cronbach's alpha value of greater than or equal to 0.70 is considered acceptable for the factor to be reliable [33]. In our case, all the factors had satisfactory value of Cronbach's alpha ranging from 0.712 - 0.94, indicating that the questionnaire enjoys good internal consistency and the factors are reliable. Results of the factor analysis are shown in Table I, which includes factor loading, explained variance, Eigen values and Cronbach's alpha for the six-factor solution.

The factor analysis results underline that the technology transferor factor is the key enabler of the TT process explaining 28% of the total variance in the data set (65.4%), which is in conformity with the findings of previous researchers [29] who argued that concreteness of technology is very important influential factor for achieving successful technology transfer. The combined explained variance for the project-level enablers (i.e. transferor, transferee characteristics or factors), equates to more than two-thirds (48%) of the total variance (65.4%). These are undoubtedly the factors that need to be carefully managed to ensure that the TT process derives the most value for the technology receiver. Generally, factors with initial eigen values lower than 1 have a poor contribution to the model [30]. The EFA reduced the data contained in 27 variables into a six influencing factors discarding two variables.

D. Regression Analysis

TABLE II: THE SINGLE REGRESSION ANALYSIS RESULT

	Beta	t value	Sig. level (p-values)
R= 0. 632			
R Square: 0. 399			
(F=24.33) (Sig = 0. 00)			
Independent Variables			
Factor 1 (Technology Transferor)	0. 452	3. 10	***
Factor 2 (Technology Receiver)	0. 374	1. 22	**
Factor 3 (Market)	0. 601	5. 16	***
Factor 4 (Finance)	0. 512	4. 50	***
Factor 5 (Government Policy)	0. 431	2. 11	**

*** implies significant at 0. 1% level of significance.

** implies significant at 1% level of significance

The conceptual model shown in Fig. 1 was tested using regression analysis. Table II details the regression analysis results based on the survey questionnaire. The results obtained through regression analysis provide some indication on the relationship between model factors and the contribution of each factor to the predictive power of the model [30], [33]. A higher value of R^2 produces greater explanatory power of the regression equation, and therefore a better prediction of the independent variable [30]. The *t*-value and the significance value both explain whether the addition of the predictor variable has a significant contribution to the model. A higher *t* value suggests a higher contribution to the model.

The combination of the independent variables explained 63.2% of the variance in achieving successful technology transfer (F = 24.3, p = 0.000), suggesting that this combination of variables does a reasonable job of predicting the successful technology transfer. It is found that, all five constructs introduced (Hypothesis 1 to 5) have significant effect on successful technology transfer. In this study, the construct of market factor (t=5.16, p=0.001) was found to be the most influential factor compared to other constructs, namely, finance factor (t=4.5, p=0.001), technology transferor factor (t=3.1, p=0.001), government policy factor (t=2.11, p=0.01) and technology receiver factor (t=1.22, p=0.01). As all the five hypotheses were supported, it was concluded that all the five constructs or factors (technology transferor, technology receiver, finance, market and enabling government policy factor) along with their sub-factors/variables constitute the conceptual model of successful technology transfer from public funded R&D institution to the industry.

VI. MANAGERIAL IMPLICATIONS

The developed TT model is especially important for public funded R&D laboratories and industries, those who seek transfer of technologies from public funded R&D labs, funding agencies and government whose objective is to leverage the investments made in public funded R&D institutions to achieve socio-economic development. The preliminary findings of this study and the developed conceptual model have brought out some key implications for the government and public funded R&D laboratories to achieve successful technology transfer and to enhance technology transfer rate. On the government part, it is necessary that the government should put in place an innovative technology transfer policy framework like the US Bayh-Dole Act that creates markets for technology transfer, provides easy access to risk finance and incentives to all stakeholders. On the other hand, the implications to technology transferor are that the technology proposed to be transferred should be investment grade and the product/service comes out of the transferred technology should be competitive in quality and cost. Furthermore, the study identified the top ten variables among the technology transferor, technology receiver, market, finance and government policy factors through an empirical validation by the academics and practitioners. All the concerned stakeholders to the TT process are therefore required to manage these variables effectively to achieve successful technology transfer and there by the envisaged benefits.

VII. SUMMARY AND CONCLUSIONS

This paper details the development of a conceptual model for managing successful technology transfer from Indian public funded R&D institutions to industry. The model was further validated using the data collected through a questionnaire survey of 734 respondents representing publicly funded R&D institutions, technology financing agencies and private sector companies. The derived model consisted of five technology transfer facilitating factors and one outcome factor of successful technology transfer. Model groupings were achieved via factor analysis. Regression analysis showed the significant relationship between each model factor to predict the successful technology transfer. The results of these empirical studies not only confirmed the conceptual model but also identified 10 critical variables that a successful technology transfer from public funded R&D laboratories to industry requires to meet, at a minimum. They are, large market size, easy access to finance, strong IPRs, field tested prototype, established techno-economic feasibility/viability, performance guarantee, competitive price and quality of the product/service, product meeting user needs, fiscal incentives provided by the government and a competent team etc.

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H. Purushotham is a senior scientist and heads the CKMNT-ARCI, Dept. of Science & Technology, Govt. of India. He has 29 years of varied experience in R&D, Teaching, Technology Management and Technology Financing in many Govt. Organizations. He holds M. Tech, MBA degrees. He has published over 60 research papers in different national & international journals/conference proceedings and filed 4 patents. He was awarded "Meritorious Young Consultant Award – 1991" instituted by Consultancy Development Centre of Dept. of Scientific & Industrial Research, Govt. of India. He is currently pursuing his PhD from Department of Business Management, Osmania University, Hyderabad, India.

Sridhar Vaithianathan is working at Department of IT and Operations, IBS, Hyderabad, India. He is an expert in Structural Equation Modeling (SEM). He was a visiting scholar at College of Business Administration, The University of Toledo, USA. His areas of interest include E-commerce, informational security, RFID and technology adoption. He teaches subjects related to IT.

Ch. Shyam Sunder (Retd.) was a professor of Marketing and Dean at Department of Commerce & Business Management, Osmania University, Hyderabad – 500 007, India. He has 35 years of teaching and research experience and guided many Ph.D scholars. Currently, he is the Director of Nizam Institute of Business Management, Hyderabad, India.