Structural Equation Modeling (SEM) Approach to Identify Critical Success Factors of Technology Transfer: an Empirical Analysis from Indian Context

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Abstract: The aim of the present study is to identify the critical success factors for successful technology transfer across the technology transfer project life cycle. The study analyzed the critical factors influencing successful technology transfer from Indian publicly funded R&D institutions to the industry. Through content analysis, 27 influencing variables were identified. The perceptions of 734 survey respondents were obtained through questionnaire survey on the relevance and importance of these 27 variables on a Likert scale. The conceptual model was proposed that included five factors which were considered to influence successful technology transfer. The survey data was analyzed using structural equation modeling (SEM) technique. The model fit indices were found to be significant for both the measurement model and structural model. The results of the SEM analysis showed that among the five factors, technology transferor factors, market factors and financial factors play a major role in successful transfer of technology. Based on these findings, recommendations to technology transferors, technology receivers and government were proposed in order to ensure and facilitate the successful technology transfer.

Keywords: Technology transfer; publicly funded Indian R&D institutions; structural equation modeling; key successful factors; Public-Private-Partnership (PPP) projects; university-industry technology transfer model

1 INTRODUCTION

India spends about 1% of its GDP on R&D every year (~US$10 billion/year) through its vast network of publicly funded R&D institutions, primarily government laboratories and universities, where thousands of technologies are being developed. In spite of several pro-active measures, large number of technologies developed in the Indian publicly...
funded R&D laboratories have remained either unexploited, or the desired impact has not been made by the transferred technologies, although a beginning has been made [1]. In a recent seminal review on technology transfer from government laboratories to industry, Tran and Kocaoglu [2] articulated that the governments in both developed and developing countries were still yet to answer adequately how to translate the huge public spending on R&D to the achievement of the country’s economic goals and thus required more investigation. Achieving higher rate of successful technology transfers from publicly funded R&D institutions enhances country’s competitiveness and brings several benefits to all its stakeholders. For example, attractive return on investment (ROI) to investors, creates new jobs for citizens, gives new products and services to the consumers to meet their needs, revenue in the form of royalties to the technology transferring institutions, taxes to government and there will be an overall socio-economic development. A successful technology transfer has a multiplier effect on the overall economy.

The technology transfer is however, a lengthy, complex and dynamic process that involves a series of nonlinear activities and processes, which requires action between multiple stakeholder groups. A review of the literature of both theoretical and empirical studies also revealed that the success or failure of a technology transfer depended on large number of variables or factors and their interrelationships across the technology transfer project life cycle [3-7]. Because of the several complexities involved in TT, management of technology transfer assumes a pivotal role in optimizing business and retaining competitive edge for both the technology transferor (publicly funded R&D institutions) and transferee (the industry) in the emerging globalized economy.

It is observed that there are very few empirical studies on management of TT, which have identified the influencing or critical variables/factors, and simultaneously examined their impact on successful technology transfer in a single integrated model [8] either in developed country or in developing country perspective. Thus, it is proposed in this study to identify the influencing or critical variables/factors across the TT process/project through a content analysis and their impact on achieving successful technology transfer simultaneously in a single, holistic model under Indian context using structural equation modeling (SEM) approach as SEM can examine series of dependence relationships simultaneously [9].

2 DEFINITIONS OF TECHNOLOGY, TECHNOLOGY TRANSFER & SUCCESSFUL TRANSFER

Theoreticians and practitioners have defined the concepts of technology transfer in many different ways. The review of literature shows that the literature lacks consensus on the definition of technology transfer. For example, Sazali, et al., [10] reported 24 definitions of technology transfer. Some of the definitions relevant to the context of this study are cited below.

*Technology* is information that is put into use in order to accomplish some task [11]. *Transfer* is the movement of technology via some communication channel from one organization to another. A *technological innovation* is an idea, practice or object that is perceived as new by an individual or some other unit [12]. *Technology Transfer (TT)* is therefore, the application of information (a technological innovation) into use [13].

In the context of the present study, technology transfer is defined as the process by which intellectual property rights (IPRs) and/or know-how developed under technology push or market pull mode is moved to the market place.

The terms, technology transfer, knowledge transfer, technology commercialization, commercialization of R&D results, technology innovation, technology valorization, technology diffusion etc are all used synonymously and inter changeably in the literature, as the activities covered and ultimate goal of all these definitions are one and the same [14, 15].

A technological innovation or technology is said to be fully and successfully transferred only when it is commercialized into a product or service that is sold in the marketplace [15].

3 LITERATURE REVIEW

A literature review was undertaken, primarily with the help of online databases Web of Knowledge, the world’s most popular and frequently used global database of choice for broad review of scientific accomplishment in all fields of study [16] along with other sources of information. The literature review reveals that most of the publications were on international technology transfer (ITT) from MNCs to private sector. The TT research from publicly funded R&D institutions to industry is just at its infancy stage not only in developing countries like India but also in many developed countries too, except USA (Fig. 1).

Several traditional models of technology transfer were suggested in the literature for use in
federal/government laboratories [17], such as the Information Dissemination Model, in which the information is made available for industry’s use; the Licensing Model, in which exclusive/non-exclusive rights are granted to a firm so that it may commercialize the technology; the Venture Capital Model, in which venture capitalists acting on behalf of entrepreneurs take an active role in determining the commercial potential of a laboratory’s technology, the Large Company-Joint Venture Model, in which companies send personnel to a laboratory and then return with the technology; and the Incubator-Science Park Model, in which support mechanisms are provided for individuals, which wish to commercialize the technology. About 148 qualitative and quantitative TT models were reported in the literature during the period 1991-2012.

Most of the TT models were conceptual in nature and only small number of these models was backed by empirical data analysis.

The literature review further reveals that application of SEM to technology management discipline was started only in early 2000s. The first paper in this area perhaps was from Sohn and Moon [18] of Korea who had applied SEM for predicting technology commercialization success index in relation to technology developer, technology receiver, and environmental factors. They identified number of measurement and latent variables/constructs, which were integrated and solved to find out the significant structural relationships among the measurement and latent variables. During the same year, Benedetto [19] modeled international technology transfer process in China using SEM. Subsequently, Sohn et al., [20], applied structural equation model for the evaluation of national funding on R&D projects to identify the best practices as well as to provide feedback information for the improvement of the government funding programs of the R&D projects of SMEs in Korea. Waroonkun and Steward [21] modeled the international technology transfer process in construction projects in Thailand using SEM, which included four TT process enablers, namely, government influence, transferee characteristics, transferor characteristics and relationship building, and one outcome factor named TT value added. The model findings revealed that building relationship between the transferor and transferee was determined to be the key predictor of TT induced value creation for the host construction sector. Lou, et al. [22] evaluated the commercialization potential of emerging technologies in China based on the structural equation model. The model findings revealed that technology commercialization success depends on technology factor, economic factor, qualification factor, consistent factor, and social factor.

Thomas Ng et al [23] prescribed a structural equation model of feasibility evaluation and project success for public-private partnership (PPP) projects in Hong Kong. The factors for evaluating the feasibility of PPP projects were classified into
five broad categories: technical, financial and economic, social, political and legal, and others. Through the structural equation modeling approach, data attained from questionnaire survey conducted in Hong Kong was analyzed and a model was developed to examine the relationship between different evaluation factors and the overall success satisfaction of stakeholders. The results indicated that the technical and social aspects were critical to the feasibility of PPP projects and therefore, were the determining factors for success.

Farhad et al. [24] proposed a university-industry technology transfer (UITT) model and validated the model from the survey data using Structural Equation Modeling (SEM). Their model consists of 5 latent factors and 15 measured variables. Behboudi et al. [25] presented a structural equation model of commercialization of research outcomes in Iran. Although this is a very good empirically validated model, but it has some limitations, like, it did not consider some of the relevant technology transferor, receiver and environmental variables. Furthermore, the rational to form different constructs, their validity and reliability were also not established.

Based on the literature review, the framework for management of successful technology transfer from public funded R&D institutions to industry is presented in Fig. 2.

The models and frameworks reviewed above offer in general a rich understanding of management of technology transfer process in different settings and reveal the key variables/factors that affect the technology transfer success of their country’s context. These models are helpful in formulating the overall structure of the proposed conceptual generic TT model suitable under Indian context.

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Based on the literature review, the framework for management of successful technology transfer from public funded R&D institutions to industry is presented in Fig. 2.

Fig. 3. Key stages in technology transfer process from public funded R&D labs to the industry

4 IDENTIFYING INFLUENCING VARIABLES OF TT

Identification of the influencing variables of successful technology transfer from publicly funded R&D institutions to the industry is the starting point for building the research model in this study. To identify these influencing variables across the technology transfer process/project, it is necessary to understand and map the process of technology transfer that is prevailing in Indian publicly funded R&D laboratories. Based on the theory, literature review and researcher’s long field experience in the area of technology development and transfer in publicly funded Indian R&D institutions, the process of how technology is being typically transferred, which we think applies for most publicly funded R&D labs in India is graphically presented in Fig. 3.

It can be seen from Fig. 3 that technology transfer can be initiated by forces related to either the technology push (laboratory/supply side) or market pull (receiver/demand side) of the process [26] and will continue until the product/service is launched in the market with stakeholders adding value to it at different stages of the process. This process emphasizes the involvement of transferor and transferee at all stages until the product/service emerging from the technology transfer is commercially produced and launched in the market.
### Table 1. Summary of identified influencing variables and their grouping into different factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Variable Name</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>1. Technology Transferor Factor</td>
<td>Strong IPRs</td>
<td>Jolly [28], Bozeman [29], Heslop [30], Kneller [31], Siegel [32], Bandarian [33], Palmberg [34], Joseph [35], Lou [22], Amadi [36].</td>
</tr>
<tr>
<td></td>
<td>Prototype Field Tested</td>
<td>Jolly [28], Joseph [26], Sundararajan [5], Khan [3], Heslop [30], Kumar [37], Andrew [38], Slater [39].</td>
</tr>
<tr>
<td></td>
<td>Exclusive Licensing of Technology</td>
<td>Sundararajan [5], Bozeman [29], Kneller [31], Chandra [40], Ray [41].</td>
</tr>
<tr>
<td></td>
<td>Training &amp; Demonstration</td>
<td>Narayana [42], Jolly [28], Gupta [43], Sung [44], Khan [3], Kumar [37], Richard [45], Jagoda [46], Sung [47].</td>
</tr>
<tr>
<td></td>
<td>Performance Guarantee</td>
<td>Sundararajan [5], Khan [3], Pandit [48], Lou [22].</td>
</tr>
<tr>
<td></td>
<td>Effective Communication</td>
<td>Williams [49], Xinping Shi [50], Sung [44], Cummings [51], Waroonkun [21], Pandit [48], Sung [47], Jagoda [46], Farhad [24].</td>
</tr>
<tr>
<td>2. Technology Receiver Factor</td>
<td>Top management champions the project</td>
<td>Joseph [26], Sung [44], Heslop [30], Kneller [31], Siegel [32], Cummings [51], Richard [45], Sohn [18], Sung [47].</td>
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<td></td>
<td>Having competent team</td>
<td>Henard [52], Lin [53], Rammohan [54].</td>
</tr>
<tr>
<td></td>
<td>Strong financial background</td>
<td>Sundararajan [5], Joseph [26], Khan [3], Bozeman [29], Kumar [37], Siegel [32], Richard [45], Li [15].</td>
</tr>
<tr>
<td></td>
<td>Prior business experience</td>
<td>Cooper [55], Xinping Shi [50], Sundararajan [5], Bozeman [29], Waroonkun [21], Mohamed [56], Farhad [24].</td>
</tr>
<tr>
<td></td>
<td>Vision &amp; Passion</td>
<td>Cooper [55], Sung [57].</td>
</tr>
<tr>
<td></td>
<td>Domain Knowledge</td>
<td>Sang [57], Mohamed [56], Amadi [36].</td>
</tr>
<tr>
<td></td>
<td>Marketing capability/skills</td>
<td>Sundararajan [5], Friar [58], Bozeman [29], Industry Canada [59].</td>
</tr>
<tr>
<td>3. Market Factor</td>
<td>Large market size</td>
<td>Cooper [60], Piper [61], Narayana [42], Friar [58], Heslop [30], Rammohan [54], Thomas Ng [23], Pandit [48], Behboudi [25].</td>
</tr>
<tr>
<td></td>
<td>Product meeting user needs</td>
<td>Cooper [60], Piper [61], Joseph [26], Heslop [30], Bandarian [33], Thomas Ng [23], Lou [22], Nazanin [27], Behboudi [25], Li [15].</td>
</tr>
<tr>
<td></td>
<td>Competitive price and quality</td>
<td>Cooper [60], Span [62], Piper [61], Joseph [26], Khan [3], Heslop [30], Kneller [31], Sohn [18], Galbraith [63], Mohamed [56], Behboudi [25].</td>
</tr>
<tr>
<td></td>
<td>First to market</td>
<td>Cooper [60], Heslop [30], Ramamohan [54].</td>
</tr>
<tr>
<td>4. Financial Factor</td>
<td>Techno-economic feasibility/viability</td>
<td>Jain [66], Khan [3], Kneller [31], Bandarian [33], Jagoda [46], Thomas Ng [23], Jinfu [67], Behboudi [25], Navig [65].</td>
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<tr>
<td></td>
<td>Easy access to Finance</td>
<td>Joseph [26], Friar [58], Khan [3], Heslop [30], Kumar [37], Cummings [51], Pandit [48], Nazanin [27], Behboudi [25], Nandagopal [68].</td>
</tr>
<tr>
<td></td>
<td>Longer repayment periods of debt</td>
<td>Kumar [37].</td>
</tr>
<tr>
<td>5. Government Policy Factor</td>
<td>Proactive legislative acts</td>
<td>Heslop [30], Bhattacharya [69], Etzkowitz [70], Waroonkun [21], Jagoda [46], Thomas Ng [23], Nazanin [27], Behboudi [25], Amadi [36].</td>
</tr>
<tr>
<td></td>
<td>Fiscal incentives</td>
<td>Pawan [71], Sung [44], Kumar [37], Pandit [48], Agarwal [72], Visalakshi [73], Sung [47].</td>
</tr>
<tr>
<td></td>
<td>Strengthening the existing financing/incubation schemes</td>
<td>Agarwal [72], Purushotham [7, 74].</td>
</tr>
</tbody>
</table>

*Continued in Next Page*
*Out of 27 variables, 18 were tested empirically by few researchers in the past.

By reviewing the literature, examination of leading theoretical/empirical TT studies/models reviewed above and performing content analysis [25, 27], we have identified 27 measured variables (Table 1) which could influence the successful technology transfer process as shown in Fig. 3.

All the 27 variables identified through content analysis were hypothetically grouped by conceptualizing their relationship with one another in the above context into five broad exogenous/facilitating factors (constructs); and one endogenous/outcome factor (construct), i.e. successful technology transfer as shown in Table 1. Subsequently, the formation of the six factors was confirmed by conducting exploratory factor analysis.

5 DEVELOPMENT OF A CONCEPTUAL MODEL AND HYPOTHESES
Research on technology transfer management has been traditionally concentrated on effective linkages and information movement, generally to the exclusion of the management theory [47].

However, researchers, off late began to argue that TT models developed based on the factors that will influence technology transfer, would have better power to predict TT outcomes and could be used as a framework for facilitating effective technology transfer [8, 13, 21, 25, 33, 44, 47, 77, 78]. Therefore, development of a conceptual model for managing technology transfer aims to capture all the relevant variables that influence the effectiveness of the TT process and the resulting transfer success. Based on the models reported earlier [1, 18, 25, 29, 44, 55], an integrated generic conceptual causal model for managing technology transfer from publicly funded R&D laboratory to the industry in terms of the variables/factors identified above (Table 1) was developed and shown in Fig. 4 which consists of five exogenous factors and one endogenous factor (successful technology transfer). Along with the technology transferor and receiver factors, the model also takes into consideration, the marketing, financial and government policy support factors, as these factors were not considered in detail in the previous models.

![Fig. 4. Conceptual model for managing technology transfer from publicly funded R&D labs to industry](image-url)
The links between the exogenous (input/independent) factors and endogenous (output/dependent factor in the conceptual model have been largely conceptualized based on literature support and from an understanding of the technology transfer process from publicly funded Indian R&D laboratories to industry. The relationship between the above mentioned factors or constructs along with their related measured variables are represented by five hypotheses as described below:

H1: Fulfilling technology transferor factor is considered as a key for successful technology transfer (has positive and significant effect).

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 the 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 variable was presented as separate hypothesis to test its influence on successful technology transfer from publicly funded R&D laboratories to industry in India.

6 RESEARCH METHODOLOGY
Since the overall research objectives of this study were to identify the factors influencing technology transfer, develop a generic conceptual model for management of TT in terms of these influential factors and examine the influence of these factors on the success of technology transfer simultaneously, technology transfer project itself is considered as the level or unit of analysis. The respondents for data collection were chosen from publicly 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 of 4288 institutions were considered to be the best respondents to evaluate the importance and effectiveness of variables pertaining to the TT process and the outcomes it could potentially generate. After analyzing the activities and relevance of the population, with regard to the context of the study and using a purposive sampling method, a sample size of 3000 respondents was chosen, out of the population/universe of 4288 for conducting the questionnaire survey.

To measure the perceptions of the respondents on the identified 27 key variables, which are likely to be influencing the success of technology transfer, we have developed a survey instrument/questionnaire primarily on the basis of the survey questionnaires reported in the literature [25, 30], 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, number of TT projects coordinated, 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 and relevance 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 [64].

The primary questionnaire survey was undertaken during September 2012 to January 2013 with the above target group/sample 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 were taken up for SEM analysis, as the sample size meets the minimum requirement of 1:15
ratio (variables: responses) for carrying out SEM [79].

7 DATA ANALYSIS AND RESULTS

The data collected through questionnaire survey was analyzed, using the statistical package for the social sciences (SPSS v16), for estimation of the Cronbach’s alpha, means and standard deviations (SD), analysis of variance (ANOVA), factor analysis. SEM (AMOS Software Package, which is available on SPSS platform) was used to carry out the confirmatory factory analysis (CFA), the inter-relationships/structural relationships between the different factors and for testing the hypotheses of the conceptual model.

7.1 Respondents Profile

The respondents of the questionnaire survey 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: less than 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%) and from across the country: southern region (41%), northern region (20%), eastern region (10%) and western region (29%).

Analysis of variance (ANOVA) was performed to ensure that respondents having different positions (e.g. scientists, technology transfer professionals, professors, R&D managers, investors, CEOs of companies etc.) and from different types of organizations (publicly funded and private sector etc.) could be considered as a single sample. The results of ANOVA (F statistic, p value) shown that the data can be treated as one usable sample [80].

The personal profiles of the survey respondents show that the participants are fairly senior, predominantly technically oriented persons having experience in diverse areas of technology development and transfer. Experience of participants from the 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.

7.2 Structural Equation Modeling (SEM)

SEM is an effective technique for conceptualizing a theoretical model, confirming relationships between variables and gaining insight into the causal nature and strength of identified relationships [83, 85]. SEM examines series of dependence relationships simultaneously and it is particularly useful in testing theories that contain multiple equations involving dependence relationships like in the present research. SEM consists of two parts. The first part is the measurement model or confirmatory factor analysis (CFA). It represents theory showing how measured variables come together to represent constructs or factors. The second part is the structural model showing how constructs are associated with each other, often with multiple dependence relationships [9]. SEM was employed in this study for two main tasks: (1) confirmatory factor analysis (CFA) to corroborate the constructs established through exploratory factor analysis (i.e. testing the measurement model); and (2) testing the structural model by testing the hypotheses using path significance analysis for every construct of the research model for the each path.

7.2.1 Measurement Model / Confirmatory Factor Analysis (CFA)

The field data collected on the above 27 variables from the 734 respondents was analyzed using exploratory factor analysis (EFA) for data reduction and summarization. The EFA retained 25 variables which were properly loaded on six factors with 65.42% cumulative variance explained. The resulting six factors were labeled as (1) Technology transferor factor (2) Technology receiver factor (3) Market factor (4) Finance factor (5) Government policy factor and one outcome factor; i.e. (6) Successful technology transfer, which were shown in Table.1. The EFA did not support retaining two variables, (first to market and domain knowledge of a technology receiver) as the factor loadings obtained for these two variables were insignificant and less than the recommended threshold factor loading (<0.5). These factors or constructs along with the respective measured variables shown in
Table 1 were the backbone for building a conceptual model for managing technology transfer and validating the same from survey data using SEM.

Specifying the measurement model (i.e. assigning variables to the constructs they should represent) based on the proposed theoretical model/EFA is a critical step in developing a measurement model. By using the graphic interface of AMOS, the measurement model is drawn and depicted in Fig. 5, which shows the linkage between the specific variable and their associated constructs along with the relationship among the constructs. Paths from the latent construct to the measured variables are based on the measurement theory. A measurement theory specifies how measured variables logically and systematically represent constructs involved in a theoretical model. A general thumb rule is that a minimum of three measured variables per latent factor or construct is needed to provide minimum coverage of the construct’s theoretical domain [9]. In our measurement model all constructs were having minimum three measured variables.

Confirmatory Factor Analysis of SEM was performed using the AMOS 16.0 (Analysis of Movement Structures) software package. AMOS is a one of the modules in SPSS, which uses a very user friendly and interactive graphic interface to draw path diagrams for the measurement and structural models of SEM using any personal computer.

Once the measurement model is correctly specified by following the standard syntax rules of SEM, AMOS software package was run to perform the confirmatory factor analysis on the proposed measurement model consists of the first order six latent factors as shown in Fig. 5, with the measurement variables loading in accordance with the pattern revealed in the exploratory factor analysis. The default estimation procedure is maximum likelihood. Table 2 shows the summary of CFA empirical results of the relationships among variables and constructs represented by the data.

Fig. 5. A Path Diagram Showing Hypothesized Measurement Specifications (Cfa)
<table>
<thead>
<tr>
<th>Latent Factor/Construct (Code)</th>
<th>Observed Variable</th>
<th>Overall</th>
<th>Confirmatory Factor Loading</th>
<th>p-value</th>
<th>AVE</th>
<th>CR</th>
<th>Cronbach Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Transferor Factor (TF) Overall mean = 4.35 S.D=0.82</td>
<td>T1 Strong IPRs</td>
<td>4.63</td>
<td>0.64</td>
<td>0.75</td>
<td>***</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>T2 Prototype field tested</td>
<td>4.57</td>
<td>0.58</td>
<td>0.92</td>
<td>***</td>
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<tr>
<td></td>
<td>T3 Exclusive Licensing</td>
<td>4.19</td>
<td>1.05</td>
<td>0.76</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T4 Training &amp; Demonstrated</td>
<td>4.24</td>
<td>0.91</td>
<td>0.88</td>
<td>***</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>T5 Performance guarantee</td>
<td>4.37</td>
<td>0.78</td>
<td>0.96</td>
<td>***</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>T6 Effective communication</td>
<td>4.09</td>
<td>0.97</td>
<td>0.96</td>
<td>***</td>
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<tr>
<td>Technology Receiver Factor (RF) Overall mean = 4.16 S.D= 1.01</td>
<td>R1 Top management champions the project</td>
<td>3.95</td>
<td>1.11</td>
<td>0.88</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R2 Having competent team</td>
<td>4.29</td>
<td>0.98</td>
<td>0.83</td>
<td>***</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>R3 Strong financial background</td>
<td>4.17</td>
<td>1.08</td>
<td>0.71</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R4 Marketing capability</td>
<td>4.23</td>
<td>0.89</td>
<td>0.72</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Factors (MF) Overall mean = 4.49 S.D= 0.70</td>
<td>M1 Large market size</td>
<td>4.75</td>
<td>0.56</td>
<td>0.99</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M2 Product meeting user needs</td>
<td>4.35</td>
<td>0.81</td>
<td>0.71</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M3 Competitive price and quality</td>
<td>4.36</td>
<td>0.71</td>
<td>0.77</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Finance Factors (FF) Overall mean = 4.47 S.D=0.83</td>
<td>F1 Techno-economic feasibility/variability</td>
<td>4.49</td>
<td>0.82</td>
<td>0.84</td>
<td>***</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>F2 Easy access to finance</td>
<td>4.73</td>
<td>0.68</td>
<td>0.90</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F3 Longer repayment period of debt</td>
<td>4.18</td>
<td>1.0</td>
<td>0.84</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government Factors (GF) Overall mean = 4.07 S.D= 0.84</td>
<td>G1 Proactive legislative acts</td>
<td>3.82</td>
<td>1.23</td>
<td>0.71</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G2 Fiscal incentives</td>
<td>4.32</td>
<td>0.86</td>
<td>0.72</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>G3 Strengthening the existing financing and incubation schemes</td>
<td>3.98</td>
<td>0.42</td>
<td>0.74</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Successful Technology Overall mean = 4.12 S.D= 1.12</td>
<td>S1 Commencement of commercial production</td>
<td>4.23</td>
<td>1.13</td>
<td>0.93</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S2 Launch of product in the market</td>
<td>4.20</td>
<td>1.05</td>
<td>0.98</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S3 Attractive Return on Investment</td>
<td>4.12</td>
<td>1.08</td>
<td>0.79</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>S4 Socio-economic development</td>
<td>3.85</td>
<td>1.24</td>
<td>0.94</td>
<td>***</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In order for a measured variable to be considered valid, it must have a factor loading of at least 0.6 with its related constructs [81]. All responses of the questionnaire were met with these criteria except two variables i.e. prior business experience of the technology receiver and vision and passion of the technology receiver, which have factor loadings of 0.412 and 0.589 respectively. Therefore, these two variables were rejected as they have a factor loading of less than the threshold factor loading of 0.6 [81]. The validity and reliability of the measurement model was carried using the remaining 23 measured variables, to see how well the theory fit the data by comparing the goodness of fit indices obtained in the measurement model with the reported standard goodness of fit indices.

7.2.2 Assessing Validity and Reliability of the Constructs of the Measurement Model

Construct validity is the extent to which a set of measured variables actually reflects the latent construct or factor they are designed to measure [9]. Construct validity was established in this study by establishing the face validity, factor loading, Cronbach’s alpha, convergent validity and discriminate validity. To test the reliability of the constructs, Anderson and Gerbing [82] suggested to use composite reliability (CR) and average variance extracted (AVE) instead of Cronbach-alpha (internal consistency of measures).

To achieve convergent validity, the factor loadings and composite reliability (CR) should be greater than 0.7 and average variance extracted (AVE) of the constructs as suggested by Fornell and Larcker [83] should be greater than 0.5. As can be seen from Table 2, all the measured variables are having significant loadings on to the respective factor/constructs (p<0.001) with values varying between 0.71 and 0.99. In addition the average variance extracted (AVE) for each construct is >0.5 and CR is >0.70, which support the convergent validity of the constructs. Discriminant validity was assessed by comparing the AVE with the corresponding inter-construct squared correlation estimates [83]. It was found from the data analysis that the AVE values of all the factors are greater than the inter-construct correlations (Table 3) which support the discriminant validity of the constructs [83]. Thus, the measurement model has an adequate validity and constructs reliability.

<table>
<thead>
<tr>
<th>Technology Factor (TF)</th>
<th>Receiver Factor (RF)</th>
<th>Market Factor (MF)</th>
<th>Financial Factor (FF)</th>
<th>Government Factor (GF)</th>
<th>Success Factor (ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Factor (TF)</td>
<td>0.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver Factor (RF)</td>
<td>0.26</td>
<td>0.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market Factor (MF)</td>
<td>0.12</td>
<td>0.35</td>
<td>0.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial Factor (FF)</td>
<td>0.04</td>
<td>0.07</td>
<td>0.22</td>
<td>0.85</td>
<td></td>
</tr>
<tr>
<td>Government Factor (GF)</td>
<td>0.10</td>
<td>0.48</td>
<td>0.52</td>
<td>0.18</td>
<td>0.64</td>
</tr>
<tr>
<td>Successful Transfer (ST)</td>
<td>0.08</td>
<td>0.07</td>
<td>0.17</td>
<td>0.29</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Note: Diagonal elements in the correlation matrix of constructs are the square root of the AVE values. AVE should be greater than squared inter-construct correlations. For discriminant validity to be present the diagonal elements should be greater than the off diagonal.

7.2.3 Assessing Model Fit of Measurement Model

The model to be acceptable, all goodness-of-fit indices should be greater than 0.9 and RMSEA should be less than 0.08 [84, 85]. As shown in Table 6, the values of the goodness-of-fit indices obtained for the measurement model indicate a reasonable fit of the measurement model with data. In short, the CFA of SEM model confirms to the six-factor structure containing 23 measured variables, which contributes significantly for the successful technology transfer from publicly funded R&D laboratories to industry. In addition to acceptable fit indices, all the 23 variables loaded significantly (p<0.001) on the respective latent constructs or factors. If the measurement model has not survived its test of reliability, validity and, do not achieve acceptable fit, the structural model validity cannot be performed. Therefore, only after the measurement model is validated and achieved acceptable model fit then only we can turn our attention to a test of the structural relationships. Since the measurement model met the above acceptance criterion, the structural model was specified and the proposed model hypotheses were tested in the structural model in the subsequent section.
7.3 Structural Model
Structural model specification focuses on using dependence relation type to represent structural hypotheses of the researcher’s model. In other words, what dependence relationships exist among factors/constructs? Each hypothesis represents the specific relationship that must be specified. In specifying structural model, we carefully select the potential key factors that influence successful technology transfer. From the experience and judgment, it is believed that there is a strong reason to argue that different variables/factors of technology transferor, technology receiver, market, finance and government policy affect the successful technology transfer. Based on the theory, we proposed the five structural relationships in the form of five hypotheses as described above and the hypothetical model shown in Fig. 4.

H₁ is specified with the arrow connecting technology transferor factor and successful technology transfer. In similar manner H₂, H₃, H₄ & H₅ are specified. In single headed arrows showing the dependence relationship between constructs represent the structural part of the model. This structural model shown in the path diagram in Fig. 4 is used to estimate the model parameters and assess its validity. The algorithms that perform SEM estimation have the goal of explaining observed covariance matrix of variables, \( S \), using an estimated covariance matrix, \( \Sigma_k \), calculated using the regression equations that represent the hypothetical model. The matrix of residuals (the differences between the observed and estimated covariance matrices \( |S-\Sigma_k| \)), becomes the key driver in assessing the fit of SEM model. If the estimated covariance matrix is sufficiently close to the observed covariance matrix (the residuals are small), then the model and its relationships are supported. All the calculations in the path analysis are handled by the AMOS computer software and it finally gives an output, which can be analyzed and reported to validate the model. The SEM program computes a model solution directly from data file without the researcher computing a correlation and covariance matrix separately.

Path analysis was undertaken using the SEM to uncover the significant interrelationships between the constructs and for testing the set out hypotheses. Table 4 highlights the inter-correlations between the five categories of latent evaluation factors or constructs. All the five factors were shown to be inter-correlated to some degrees. Strong interrelations were found between Government Policy Factor and Market Factor (correlation coefficient = 0.72), Government Factor and Technology Receiver Factor (correlation coefficient = 0.70), Market Factor and Technology Receiver Factor (correlation coefficient = 0.6). It can be seen from the Table 4 that Government Policy Factor significantly influences Market Factor, Finance Factor and Technology Receiver’s Factor.

### Table 4. Correlation coefficient between the factors/constructs

<table>
<thead>
<tr>
<th>Correlation Path</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Factor (TF) ↔ Receiver Factor (RF)</td>
<td>0.51</td>
</tr>
<tr>
<td>Receiver Factor (RF) ↔ Market Factor (MF)</td>
<td>0.60</td>
</tr>
<tr>
<td>Market Factor (MF) ↔ Finance Factor (FF)</td>
<td>0.47</td>
</tr>
<tr>
<td>Finance Factor (FF) ↔ Government Factor (GF)</td>
<td>0.43</td>
</tr>
<tr>
<td>Technology Factor (TF) ↔ Market Factor (MF)</td>
<td>0.35</td>
</tr>
<tr>
<td>Technology Factor (TF) ↔ Finance Factor (FF)</td>
<td>0.20</td>
</tr>
<tr>
<td>Technology Factor (TF) ↔ Government Factor (GF)</td>
<td>0.32</td>
</tr>
<tr>
<td>Receiver Factor (RF) ↔ Finance Factor (FF)</td>
<td>0.26</td>
</tr>
<tr>
<td>Receiver Factor (RF) ↔ Government Factor (GF)</td>
<td>0.70</td>
</tr>
<tr>
<td>Market Factor (MF) ↔ Government Factor (GF)</td>
<td>0.72</td>
</tr>
</tbody>
</table>

7.3.1. Testing of Hypotheses
The second step in the SEM model is testing the hypotheses formulated using path significance analysis for each construct of the research model for each path by computing the path coefficient /standardized estimates and path significance. All the hypotheses were tested empirically in the context of successful technology transfer from publicly funded R&D laboratories to industry using the AMOS software package. Table 5 summarizes the results of hypotheses testing, showing the respective path coefficient /standardized estimates and path significance, p-values. It was found that all five constructs introduced (Hypothesis 1 to 5) have significant and positive effect on successful technology transfer and therefore, confirm all five
hypotheses proposed. In doing so, this research sheds light on the relationship between different technology transfer factors on successful technology transfer from publicly funded R&D laboratories to industry. In this study, the construct of market factor with the path coefficient of 0.723 (p<0.001) was found to be the most influential and significant factor compared to other constructs, namely, finance factor 0.619 (p<0.001), technology transferor factor 0.523 (p<0.001), government policy factor 0.507 (p<0.01) and technology receiver factor 0.476 (p<0.01). The similar kind of trend was also found when we computed the overall factor/construct means of the measurement model (Table 2). This shows the robustness of the data and the model.

### Table 5. Hypotheses testing results

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Hypothesized path / Structural relationship</th>
<th>Standardized Estimates</th>
<th>P-values</th>
<th>Is hypothesis Supported?</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1: TF → ST</td>
<td>Technology (TF) → Success (ST)</td>
<td>0.523</td>
<td>***</td>
<td>YES</td>
</tr>
<tr>
<td>H2: RF → ST</td>
<td>Receiver (RF) → Success (ST)</td>
<td>0.476</td>
<td>**</td>
<td>YES</td>
</tr>
<tr>
<td>H3: MF → ST</td>
<td>Market (MF) → Success (ST)</td>
<td>0.723</td>
<td>***</td>
<td>YES</td>
</tr>
<tr>
<td>H4: FF → ST</td>
<td>Financial (FF) → Success (ST)</td>
<td>0.619</td>
<td>***</td>
<td>YES</td>
</tr>
<tr>
<td>H5: GF → ST</td>
<td>Government (GF) → Success (ST)</td>
<td>0.507</td>
<td>**</td>
<td>YES</td>
</tr>
</tbody>
</table>

Note: *** implies path coefficients significant at 0.1% level of significance. ** implies path coefficients significant at 1% level of significance.

The study concludes that all the five proposed hypotheses were found to be true as they have significant and positive effect on successful technology transfer and constitute the model for management of successful technology transfer from publicly funded R&D laboratories to industry. Fig. 6 shows the SEM for management of TT from publicly funded R&D laboratories to the industry with all the estimated parameters.

### 7.3.2 Assessing the Structural Model Validity

The overall fit of the structural model was assessed using the same criteria as the measurement model. The model fit indices of structural model obtained were compared with the model fit indices of measurement model and are shown in Table 6. To achieve an acceptable measurement and structural model, all fit indices should be greater than 0.9, RMSEA should less than 0.08 and $\chi^2$/DF or CMIN/DF should be <5.0. Since all the fit indices obtained are within the acceptable range of a goodness of fit indices reported in the literature, it suggests that the SEM provides a good overall fit.

### Table 6. Comparison of the goodness of fit between the measurement and structural models

<table>
<thead>
<tr>
<th>Model</th>
<th>Goodness of fit indices (GOF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\chi^2$</td>
</tr>
<tr>
<td>Measurement model</td>
<td>616.04</td>
</tr>
<tr>
<td>Structural model</td>
<td>703.04</td>
</tr>
</tbody>
</table>

Comparison of goodness of fit (GOF) indices between the measurement model and structural model further establish and strengthen the validity of the structural model. Generally, the closer the structural model goodness of fit (GOF) comes to the measurement model, better will be the structural model fit, because of measurement model fit provides an upper bound to the GOF of a conventional structural model. The CFA/measurement model fit provides a useful baseline to assess the structural or theoretical fit. A recursive structural model cannot fit any better (have a lower $\chi^2$) than the overall CFA [9]. It can be seen from Table 6 that the $\chi^2$ GOF for measurement model is less than the $\chi^2$ GOF of the structural model. This is because the measurement model assumes that all constructs are correlated with one another (correlation relationships). But in the
structural model, relationships between some constructs are assumed to be zero [9]. Table 7 shows the overall integrated model fit indices obtained for the final SEM in comparison to the recommended model fit indices reported in the literature to accept the model.

Fig. 6. Estimated SEM for TT from publicly funded R&D laboratories to the industry
Based on the estimated model parameters as detailed above and according to the SEM theory [9], the overall SEM equation to predict the successful technology transfer success potential of a given technology transfer project is proposed as under:

\[ Y_{\text{Successful technology transfer}} = 0.523 \times (\text{Technology transferor factor}) + 0.476 \times (\text{Technology receiver factor}) + 0.723 \times (\text{Market factor}) + 0.619 \times (\text{Finance factor}) + 0.507 \times (\text{Government policy factor}) \]

The results of SEM path diagram reveal that the factor loading and path coefficient of all factors/constructs are more than 0.71 and 0.476 respectively and statistically significant. Therefore, the theoretical model resulted from SEM path diagram analysis confirms the cause and effect relations of the factors of empirical model as well. The causality relations considered are non-recursive. Finally, based on these results the model developed for managing successful transfer of technology from publicly funded R&D laboratories to industry was found to be satisfactory.

8 SUMMARY OF FINDINGS AND RECOMMENDATIONS

The findings of this study have some key implications for technology transferors, government and companies seeking technology transfer from publicly funded R&D laboratories. If these implications are understood well before hand and addressed adequately while planning for technology transfer projects, they would facilitates successful technology transfer of a chosen technology. Salient findings of SEM along with their practical implications are presented here.

**Technology Transferor Factor:** The key two variables, providing performance guarantee and prototype field tested successfully prior to transfer by the technology provider are found to have highest correlation with the “technology transferor factor” with a factor loading of 0.96 and 0.92 respectively in comparison to other variables, i.e. effective communication (0.90), training and demonstration (0.88), exclusive licensing of technology (0.76) and strong IPRs (0.75). From this study it was found that providing performance guaranty by the technology transferor is one of the most important critical variables and the technology transferor should consider this aspect while transferring technology as it minimizes technology scale-up risk to the technology receiver. It is therefore, recommended that the publicly funded R&D institutions may fulfill all the above six variables in adequate measure to achieve successful technology transfer.

To ensure successful technology transfer, the technology transferor should also evaluate the technology receiver capabilities objectively, particularly the financial strength, marketing capability and whether the receiver has strong team

---

### Table 7. Fit indices of the final SEM

<table>
<thead>
<tr>
<th>Goodness-of-fit measure (GOF)</th>
<th>Recommended level of GOF measure</th>
<th>GOF measure obtained in final SEM</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \chi^2 ) degree of freedom or CMIN/DF</td>
<td>Recommended level&lt;5.0</td>
<td>3.62</td>
<td>Ganguli [86], Marsh and Hocevar [87], Waroonkun [21], Hair [9]</td>
</tr>
<tr>
<td>Root mean square error of approximation (RMSEA)</td>
<td>&lt;0.05 (Ideal)</td>
<td>0.053</td>
<td>Browne [88], Armstrong [89], Garson [90]</td>
</tr>
<tr>
<td></td>
<td>&lt;0.08 (Acceptable)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Threshold level=0.10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trucker-Lewis index (TLI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.911</td>
<td>Ashok [91]; Armstrong [89], Hu [92]</td>
</tr>
<tr>
<td>Comparative fit index (CFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.915</td>
<td>Armstrong [89]</td>
</tr>
<tr>
<td>Normal fit index (NFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.912</td>
<td>Armstrong [89]</td>
</tr>
<tr>
<td>Incremental fit index (IFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.915</td>
<td>Byrne [93]</td>
</tr>
<tr>
<td>Relative fit index (RFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.907</td>
<td>Ganguli [85]</td>
</tr>
<tr>
<td>Goodness of fit index (GFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.913</td>
<td>Armstrong [89], Garson [90]</td>
</tr>
<tr>
<td>Adjusted Goodness of fit index (AGFI)</td>
<td>0 (no fit) to 1 (perfect fit)</td>
<td>0.903</td>
<td>Armstrong [89], Garson [90], Hatcher [94]</td>
</tr>
</tbody>
</table>
in all functional areas as these variables were found to have a strong bearing on achieving successful technology transfer.

Developing an innovative technology by publicly funded R&D institutions may be a necessary condition but not a sufficient condition to achieve successful technology transfer. Apart from developing an innovative technology the publicly funded R&D laboratories need to strengthen their market research analysis capabilities to assess the market potential/size for the product/service that is emerging from the contemplated technology transfer project. Most of the technologies transferred by the publicly funded R&D institutions lack the market research part as they do not have such capabilities in-house and these institutions need to strengthen their market orientation capabilities [43] to achieve the success in technology transfer.

Technology Receiver Factor: In “technology receiver factor” the variable, top management championing technology transfer project with factor loading of 0.88 has the highest loading compared to the having competent team (0.83), having marketing capability (0.72) and strong financial background (0.71). From this study it was discovered that under Indian conditions top management championing the project is one of the top key variable to achieve successful technology transfer along with maintaining required strength in the other three significant variables.

The survey findings and the structural equation model (SEM) show that the marketing factor was the most dominant factor followed by the finance factor to achieve successful technology transfer. Therefore, the technology receiver should assess and satisfy himself about the market potential of the product/service, ability to market the product/services and raise the required financial resources across the project life cycle. In view of the above, it is strongly recommended that before setting up of a venture based on technology transfer from publicly funded R&D institutions, the technology receiver should thoroughly assess the technology/its transferor capabilities, market, competition, feasibility/viability, government policies/regulatory procedure, incentives available the right team in place, understand the overall financial requirement and possibilities/alternatives to achieve timely financial closure.

Market Factor: In the construct, “market factor” having large market for the product/service with factor loading (0.99) has the highest correlation with the construct in comparison to the other variables i.e. competitive price and quality (0.77) and product meeting user needs (0.71). From this study, it was found that evaluating the credible market size, coupled with competitive price and quality for the product or service are the key critical variables/factors for achieving successful technology transfer.

Financial Factor: In the construct, “financial factor” the variable of easy access to finance for commercializing new technologies with factor loading of 0.96 is highly in correlation with this construct compared to the variables of techno-economic feasibility/viability (0.84) and longer repayment periods of debts (0.84). Access to finance was found to be the second most critical variable with factor loading of 0.96, after large market size (0.99), among all the 19 input variables studied. Easy and timely availability of the required term loan and working capital at different phases of the project life cycle play a crucial role in making the technology transfer project successful. However, availability of early stage finance either in the form of soft loan/debt or equity is a major bottleneck in developing countries like India particularly for first generation entrepreneurs and for unproven risky technologies transferred by publicly funded R&D institutions. There are many cases in the history where many technology projects were fore closed in the mid way due to the lack of availability of required finance [7]). Creation of government owned Venture Capital (VC) and low cost debt funds in different ministries exclusively for commercialization of technologies transferred by the publicly funded R&D institutions particularly to meet early stage fund requirements will go in a long way. Initiatives similar to this have been started by the Department of Biotechnology, Government of India few years ago, but still there is a need to emulate such funding schemes in other government departments with sufficient funds.

Government Policy Factor: In the construct of “enabling government policy factor”, strengthening the existing technology financing schemes including the incubation support schemes with factor loading of 0.74 has the highest correlation with this construct in comparison to the fiscal incentives (0.72) and proactive government policies (0.71). Results of the inter-correlation coefficients (Table 4) further confirm that the government policy has a strong influence on market (GF→MF; 0.72), technology receiver (GF→RF; 0.70), finance (GF→FF; 0.43) and on technology transferor (GF→TF; 0.32). Government therefore should
provide the required stimulus through various policy initiatives and Acts. For example:

- Bringing out suitable legislative Acts like, Bayh-Dole Act 1980, Stevenson-Wyler Technology Innovation Act 1980, Federal Technology Transfer Act 1986, Technology Transfer & Commercialization Act 2000 of USA, etc. [2] which were proved to brought out a significant and revolutionary benefits in the innovation eco-system in the USA. It was reported that the Bayh-Dole Act had been instrumental in contributing more than USD 40 billion to the US economy, and in creating more than 26,000 new high-tech jobs every year [95]. It may be noted, that prior to these Acts technology transfer was not a part of the mission of publicly funded R&D institutions and as a result, government labs made very limited effort in pushing the technologies developed at their institutions to the market place and success of technology transfer from government research labs to the industry were exceptions rather than norms [2]. The similar situation is prevailing in most of the Indian Publicly funded R&D institutions. Therefore, there is a strong need to learn lessons from the technology transfer legislative Acts from the developed countries like USA and bring in suitable Acts immediately, which stimulate and improve technology delivery system in our country [73].
- Providing tax/ fiscal benefits/ incentives to all stakeholders in TT/credit guarantee for the commercialization of new technologies to encourage investors, entrepreneurs and transferors to take up the innovative projects.
- Allowing long repayment periods of loans/debt borrowed for the implementation of technologies transferred from the publicly funded R&D institutions will ease the financial burden during its early commercialization phase and facilitate stabilizing the operations there by achieving successful technology transfer. Governments may formulate a policy and direct banks and financial institutions to allow the long repayment period (say 10 years) of loan/debt that the techno-preneurs borrow from these institutions as it is allowed in infrastructure projects.
- The financial resources made available through some of the recent initiatives by the Government of India (NMITLI program of CSIR, SBIRL,BIRAC and BIPP of DBT, PRDF,TDB and NSTEDB of DST, etc.) were limited as being scarcely distributed over several funding agencies. There is a strong need to strengthen these initiatives with more financial and human resources and make the terms and conditions to avail the assistance on liberal terms particularly for the first generation innovators with regards to the collateral securities they need to provide to avail the assistance.
- The field research and case studies [7, 74] revealed that the technology business incubation support schemes available in the country significantly facilitated for the successful technology development and transfer particularly for first generation entrepreneurs. Therefore, government may establish incubation centres based on cluster approach in universities located in all large metros/cities/towns.

The global experience also reveals that government creates an environment conducive for promoting the technology transfer from publicly funded R&D laboratories to industry by market creation, removing the market imperfections, providing necessary policy push and tax benefits, etc., which facilitated implementation of large number of innovative technology projects [29].

**Successful Technology Transfer Factor:** Finally, in the dependent latent variable or construct of “successful technology transfer factor”, commencement of commercial production with factor loading of 0.98, launching of the product in the market with factor loading of 0.94, attractive return on investment (ROI) with factor loading of 0.93 have the highest correlations with the construct relative to other outcome variable of socio-economic development (0.79). The study found that commencement of commercial production and launch of product in the market are the two initial precursors to gain the long term benefits of achieving attractive return on investment (ROI) and socio-economic development. Therefore, the technology transferor should not think the whole TT process is completed and successful, once the sale of technology is completed. The technology transferor should handhold the technology receiver until the product is launched successfully in the market and accordingly plan the resources allocation to the technology transfer project.

The research study examined and brought out the impact of various factors on achieving successful technology transfer. To ensure successful technology transfer, the technology transferor and receiver need to manage effectively 23 critical variables emerged from the SEM study.

**9 SPECIFIC CONTRIBUTIONS AND VALUE ADDITION TO RESEARCH**

A large portion of the previous studies were predominately focused on the international technology transfer process and very limited studies
were focused on the technology transfer from publicly funded R&D institutions to the industry. Some of these empirical and qualitative studies resulted in the development of the frameworks or models of the TT process specific to those countries. However, none of the previously published models from other countries can be adopted straight away under Indian conditions because of the differences in cultures, capabilities/maturity of the institutions, entrepreneurial eco-system, markets, government policies and regulatory environments, etc. In an attempt to fill this gap in the knowledge, this research has developed a model for managing TT from the Indian publicly funded R&D institutions to industry, capturing all of the key variables/factors that influence the effective and successful technology transfer and validated the model with empirical data collected from the stakeholders using SEM. This research study offers the significant contributions to the existing body of knowledge in the TT research area.

In general, this study is the first attempt for developing a comprehensive model for managing technology transfer (TT) from publicly funded R&D laboratories to industry using SEM, wherein the measurement model (confirmatory factor analysis) and structural model (path analysis) have been conducted simultaneously using AMOS software package. The model was confirmed as the hypotheses were found to be true and statistically significant.

- The study has identified 10 critical variables within the five factors, which could influence the successful technology transfer. They are (i) existence of an adequate market demand or market size (mean=4.75), (ii) easy access to an early stage finance (mean=4.73), (iii) strong IPRs,(mean=4.63), (iv) field tested proto type successfully (mean=4.57), (v) techno-economic feasibility/viability (mean=4.49), (vi) performance guarantee (mean=4.37),(vii) competitive price and quality of the product/service (mean=4.36), (viii) product meeting user needs (mean=4.35), (ix) fiscal incentives provided by the government (mean=4.32) and (x) having competent team (mean=4.29), etc. These factors can serve as a thumb rule to assess the technology transfer readiness by the technology receiver and investor.
- Out of the 27 variables studied, 18 were previously tested empirically by the different researchers relevant to the context of their countries. Along with the 18 variables, 9 variables were thought to be relevant to India, which were identified based on the published literature but had not been not tested empirically and validated their significance earlier. After testing all the 27 variables, in the model, 2 variables out of the 18 variables already tested empirically in developed countries perspective, were not found significant under Indian conditions (First to market and domain knowledge of the technology receiver). Similarly out of the 9 variables chosen for testing empirically for the first time, 7 were found to be significant and 2 variables were found to be insignificant (prior business experience, vision and passion of the technology receiver). This is one of the original contributions to the existing body of knowledge in the TT area.

10 LIMITATIONS OF RESEARCH
Despite the exhaustive research method has been followed to generate the most comprehensive/generic TT model, the research is bound to have some limitations, as this is a pioneering study in Indian context. Some of the limitations observed are highlighted here.

- First, in India there is not a strong tradition of survey research in the area of technology transfer as it is still at a very primitive stage [37]. It requires a great deal of personal persuasion to get an adequate response from the respondents. Carrying out empirical research involving laboratory directors, senior scientists, academicians and industry CEOs, senior R&D managers from the industry as respondents was scarce in India. The lack of experience to participate in paper-pencil research on the part of study respondents may have affected the quality of data collected in this study [43].
- Second, most of the data collected in the study is perceptual in nature. In the absence of any objective data to compare with, perceptual data may have limited appeal to some stakeholders [43]. However, a great deal of published business management and marketing literature are based on perceptual data. Some may even argue that the perceptions are even more important than the reality based on a single case they are generally formed over a long period of experience.
- Third, the subject chosen for the study i.e. technology transfer from Indian publicly funded R&D institutions to industry being pioneering one and vast, the study does not focus on any specific sector, and is therefore may be more in the nature of exploratory research.
- Fourth, the major objective of the study was to develop a generic model of technology transfer from publicly funded R&D institutions to
industry and to have survey responses from wide range of sectors from both government and private sectors. However, at the end of the survey we found that, majority of the respondents (64%) were from the chemical, pharma and bio-pharma sectors, therefore this may limit generalization of results to the entire population across all industry verticals.

- Fifth, there were very few respondents from defence, space, atomic energy, therefore, the model may not be applicable to these strategic sectors.
- In spite of the above limitations, the study does provide an important information on how the technology transferor can better position their technologies to transfer to industry successfully.

11 SCOPE FOR FURTHER RESEARCH

This empirical study is a response to the need for statistical evidence that has typically been lacking in the literature of technology transfer from publicly funded R&D institutions to industry particularly in the Indian context. Notwithstanding the limitations brought out in the foregoing paragraphs, the researcher is convinced that the findings reflect the present state of affairs. The following suggestions are made for carrying out further research in this emerging area of technology transfer.

- As a pioneering study under the Indian context, we have identified 23 critical variables and five factors or constructs which influence the success of TT process from publicly funded R&D institutions to industry. This may prove to be a good foundation and future research can be built on this by exploring more variables/factors.
- More research is required in the area of model application. To establish the robustness of the model, the model may be applied and studied on narrow areas of different industrial sectors like, electronics, IT& ITES, energy, food and agriculture, construction, medicine, defence production etc. with adequate sample size and outcomes can be compared.
- The model may be applied on more number of case studies to benchmark different variables identified by the model and to identify new and significant variables missed if any.
- The linkage between industry and publicly funded R&D institutions/academia and the role of incubators, mentors, technology parks and other new constructs/factors may be introduced in the SEM as they are also emerging as key drivers and the impacts of these factors on successful technology transfer can be studied.

12 CONCLUSIONS

This research made a fundamental contribution in three areas: (1) identifying the influencing variables/factors of technology transfer from publicly funded R&D institutions to the industry (2) formulation of a conceptual model for managing successful TT in terms of the identified factor and (3) validating the model empirically and statistically from the primary survey data using SEM.

The conceptual model for management of TT was developed after reviewing numerous TT studies conducted in a wide variety of industry sectors. The refined and pilot testing questionnaire was utilized for the primary study. Using information collected from 734 respondents representing technology development, transfer and implementing professionals from both government institutions and private sector companies, a series of data compilation and analysis steps were undertaken. The findings brought out 23 critical variables that would facilitate successful technology transfer and a model for TT, which included five TT process facilitating factors/enablers, namely, technology transferor factor, technology receiver factor, market factor, financial factor, government policy factor and one outcome factor named successful technology transfer. Whilst, the TT model was developed only by using a sample data obtained from the Indian technology development, transfer, and implementing professionals, it could be easily adapted to suit other developed and newly industrialized countries as well.

Acknowledgements

The author (corresponding) expresses his sincere gratitude to Dr. G. Sundararajan, Director, International Advanced Research Centre for Powder Metallurgy & New Materials, (Dept. of Science & Technology, Govt. of India), Hyderabad, for granting permission to pursue the research work.

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