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Identification and evaluation of critical factors to technology transfer using AHP approach

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ABSTRACT

Technology Transfer (TT) process has been one of the most important activities in management of innovations in products, processes and services. It has been realized that critical factors (CFs) related to TT process need to be identified and evaluated. In this study, an attempt is made to analyze ranking of CFs of technology transfer. Twenty four CFs have been sorted by carrying out extensive review of literature and categorized in to five dimensions using experts' inputs. Analytical Hierarchy Process (AHP) methodology has been identified to be used for ranking of dimensions and CFs of technology transfer. All pair wise comparisons dealt with in AHP were made on the basis of opinions of experts. 'Regulatory concerns' has been prioritized as most important dimension of technology transfer. 'International bodies', 'Government authorities' and 'Environmental concerns' have been rated top three most important CFs based upon overall weight values of CFs. A conceptual model of interactions among these critical factors has also been presented which has further facilitated towards: proposing strategic framework; identifying practical and strategic implications; and deducing a strategic action plan for technology transfer process. This paper may help managers/practitioners to evaluate critical factors of technology transfer process towards achieving cost effective TT implementation and efficient management of resources.

1. Introduction

Technology transfer (TT) has increasingly been emerging as a recent and relevant topic of research among businesses, industries, nongovernmental firms, governments and of course academicians in last few years around the globe as well as in India. TT has also been identified as a very useful approach to gain competitive leverage over other firms/supply chains (SCs) [1]. Organizations may have various ways to explore their technological assets towards increased profitability and multi dimensional overall growth; however, internal exploitation of technological assets (through perceiving, planning, designing, developing, fabricating/manufacturing, and marketing/selling of products, processes and services) has been important, interests in exploitation through TT externally have intensified in recent years [2]. In developing country like India, TT may be one among possible solutions for improvement/growth of economic and industrial sectors; however, TT success may significantly depend upon appropriate choice of right technology from right source [3].

Technology transfer yet not received due consideration in policy development in most of countries undergoing the process of development [4-7].

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Technology transfer may be very helpful to provide implications for developing and less developed countries to solve technological, economic, environmental and social problems [8]. Moving innovative ideas from the research lab through production, marketing, and sales to the customer in a timely profitable manner has proven to be a difficult challenge even for the best managed business organizations. Therefore, it is crucial to recognize critical factors and develop theories for effective and efficient technology transfer [9].

Researchers need to: identify critical factors; conceptualize and understand theories and perspectives which may continue to influence TT implementation to relate and explain practical and empirical aspects of TT concept [10]. 'Critical factors', as a term initially used in the world of data analysis and business analysis, are key factors/enablers/activities essential towards success of any business/phenomenon to happen, which are required to be identified, evaluated and focused [11].

Hence, there has been a strong need to identify and evaluate critical factors of effective technology transfer process in Indian perspective. In that way, the objectives of the present research are as follows:

i. Identification of critical factors of effective technology transfer process;
ii. Evaluation of identified critical factors of effective technology transfer process in Indian perspective;
iii. Development of the conceptual strategic action plan for effective technology transfer process in Indian perspective

Literature review along with experts' opinions has been used to identify critical factors of effective technology transfer. Literature review has been found a valid approach and necessary step in appropriately structuring research field [12-13]. Further, AHP methodology has been identified appropriate to evaluate these critical factors because of the following reasons [14-21].

AHP is well established methodology that was developed by Saaty in 1977. It has been increasingly utilized to compare alternative solutions with reference to a criterion, in pair wise mode and resulting priorities may be utilized to compare and rank alternatives. Comparisons are based upon experts' opinions so may be found relevant for present scenario. The methodology checks for consistency using consistency index. The AHP technique is simple, systematic, scientific, dependable, and user friendly at the same time because of availability of suitable software to calculate priority matrices from comparison matrices.

Paper is organized as below: review of relevant literature is provided in Section 2. Critical factors of TT process are recognised through extensive literature review and provided in Section 3. Research framework and methodology used in the present research is explained in Section 4. Analysis of data and results are provided in Section 5. Discussions on findings are offered in Section 6. Important and noticeable implications of the research are suggested with strategic action plan for TT implementation (Section 7).Finally, and concluding remarks are presented with limitations and scope for future work.

2. Literature review

This section outlines the Technology Transfer (TT) process and major contributions in the field of TT and development of conceptual framework to understand TT performance. The details have been provided in the following sub sections.

2.1. Technology transfer

With the rapid advancement of technology, product life cycle is shortening continuously. In order to compete against other firms in fiercely competitive global markets, a business organization has to keep developing new technologies to differentiate it from competitors[22].Technology may be referred to a complex phenomenon comprising of know-how and techniques and may be recognized as a system of applied useful knowledge manifested or embodied in human beings and physical objects; and this transfer process from 'industrialized/developed countries' to yet 'developing ones' may not be possible without moving into formal agreements and following formal procedures [4]. Organizations have been adopting advance technologies to meet existing challenges towards new/better products, processes/activities, services and practices for delivering higher efficiency and effectiveness [19].Inter organizational technology transfer (ITT) is a key component of business organizations' innovation processes [23].

Technology transfer is one of the major challenges for the societies and business organizations in global economy. In fact, it is a complex process through which technology moves from outside sources to the organization/supply chain/country and complexity of this transfer process has been examined by growing number of researchers whose findings have been found useful in technology policy decision making [24].

2.2. Major contributions in TT

Al-Mabrouk and Soar (2009) analyzed major issues for successful information technology (IT) transfer in Arab countries. Findings suggested that the coding approach and synthesis procedures resulted in a master set of ten major issues categories for successful IT transfer [25]. Sung et al. (2009) identified factors influencing technology transfer and examined the role of these identified factors on success of technology transfer in Korean IT industry. Results reported that 'Concreteness of Technology' as the most influential factor for technology transfer [9]. Canto et al. (2012) explored critical factors that had an impact in successful transfer of manufacturing technology by taking data from 12 plants in the state of Yucatan, Mexico with corporate headquarters in the US and Italy [26]. Lee et al. (2010) explored the most critical factors of the technology transfer of equipment by taking a case example of TFT-LCD) industry in Taiwan. A comprehensive framework was established for evaluating and selecting new equipments by using various methodologies viz. fuzzy Delphi method, interpretive structural modeling and fuzzy analytic network process [22]. Lee et al. (2012) investigated the priority factors for the transfer of technology through AHP methodology and correlation analysis. Results suggested that emerging technology and bargaining power dimensions of measures should be considered in the process of decision-making towards successful implementation of TT process by business organizations [17]. Mohamed et al. (2012) identified and analyzed key factors of TT performance in the Libya's petroleum industry. Results suggested that government support and technology learning capability factors should be considered as the key predictors of TT performance [3].

Malik and Hattasinghe (2013) identified and analyzed the main human resource barriers to technology transfer by taking case studies of sixteen multinational corporations' subsidiaries in Thailand. Findings suggested that the lack of basic skill set and techniques is key barrier to technology transfer. Human skills and knowledge of technologies will help them absorb more complex knowledge whilst participating in technology transfer projects [27]. Jung et al. (2014) identified the success and failure factors of technology commercialization in public R&D. Korea. They also investigated the barriers to various stages of technology commercialization. Results suggested that 'Marketing capability' and 'Cooperation with developer' were reported the most critical factors for the success and failure of technology commercialization. While, 'Insufficiency of funds', 'Deterioration of market condition' and 'Insufficiency of marketing capabilities' were reported the top barriers to technology commercialization [28].

Kaushik et al. (2014), in their work, made extensive literature review to know background of TT and major contributions given by various researchers in the field of TT .Various enablers and barriers of technology transfer process implementation have been identified through literature support. Based upon findings, TT conceptual model was proposed [1]. Leischnig et al. (2014) empirically explored the role of alliance management capability; organizational compatibility and interaction quality in inter organizational technology transfer. Results explained linkages between important antecedents and consequences of interaction quality to understand the inter-organizational technology transfer process success [23]. Battistella et al. (2015) made extensive literature review and identified the critical factors for technology/knowledge transfer. They proposed structure consisting of six categories related to the actors involved (sources, recipients and intermediaries) [29]. Kumar et al. (2015) analyzed technology transfer critical barriers towards making technology transfer process implementation successful.AHP methodology was utilized to analyze the critical barriers of technology transfer in supply chain and provided a benchmarking framework. Finally, a single numeric value index (Technology Transfer Barriers Mitigation Index (TTBMI)) was proposed to present capability of supply chains to manage technology transfer barriers [19].

2.3. Motivation for research

Input-output model on technology transfer process showing importance of enablers of TT process has been conceptualized and presented in Fig. 1. The need of evaluating importance of enablers as presented in this Input-output model has inspired the authors to carry out the present research.

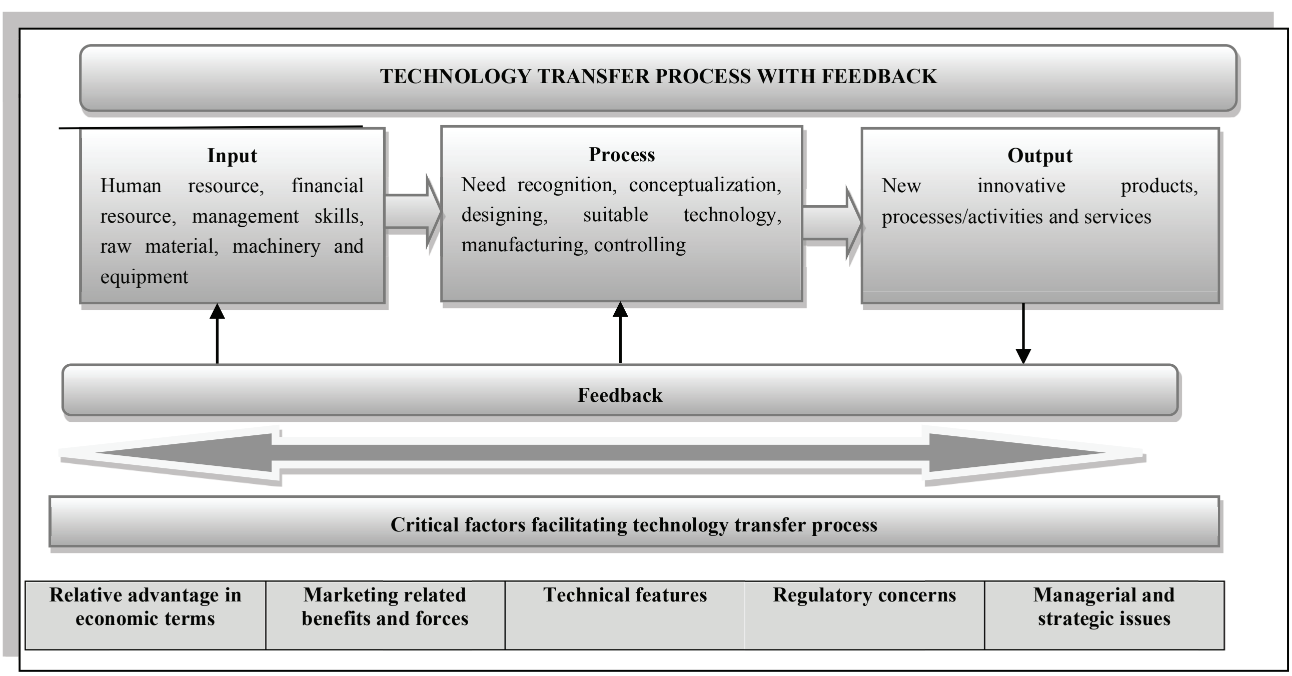

Fig. 1 - Input-output model on technology transfer process (modified from [1]).

From literature review, it is clear that TT is an important process form the point of view of organizations, while, on the other hand, it is a complex process. Therefore, it becomes necessary to identify critical factors for effective TT process. Next section deals with identification of critical factors of TT.

3. Identification of critical factors of TT

Successful TT implementation enablement has increasingly been very vital perspective for technologists and managers; and important enablers/critical factors (CFs) are required to be identified and managed. Critical factors are those factors, where are necessary for success [30]. For accomplishing this task of identifying CFs of technology transfer process literature survey was done by searching different key words such as technology transfer, constructs of TT, factors supporting technology transfer, success factors of TT and critical success factors of TT etc.. Various databases (Emerald; Science direct; DOAJ; Scopus; Google scholar and Google search) have been utilized for collecting supporting literature (several research papers published in journals and conferences proceedings having above said key words). Five critical factors dimensions having twenty four constructs have been sorted from literature review and expert's inputs are detailed below:

3.1 Relative advantage in economic terms (RA)

Relative advantage may refer to the degree to which new technology is perceived and evaluated improved in social, economic, functional, satisfaction and convenience parameters when compared with existing technology [31], we have considered only economic advantages and benefits in this work.

3.1.1 Cost effectiveness (CE)

One of most important key driver behind implementation of TT process is to achieve cost effectiveness [32-33]. Also, Leonard-Barton and Sinha (1993) found strong positive relationship between: cost effectiveness as a motive, success factor and outcome; and technology transfer implementations as a process seeking various inputs [34].

3.1.2 Higher margins of profit (HM)

Technology has been identified with its dynamic nature as one of the significant characteristics under competitive environment because of the reason of being customized and accelerated over time and in order to increase profits, the evaluation of TT initiation and adoption is becoming increasingly important [17].

3.1.3 Expected increase in sales (ES)

Joint ventures with strong technological partnership may help in developing unique technological capabilities to establish advantage over other competitor firms in foreign markets in terms of expected increase in sales volumes [35-36].

3.2 Marketing related benefits and forces (MB)

Effective marketing efforts are required to be focused to increase innovative willingness organizations to provide information regarding benefits and knowledge of their products and processes of production to organizations in countries in developing phase targeted as perspective markets [37].

3.2.1 Penetration in new areas (PA)

Technological knowledge may help organizations to upgrade products and processes, increase customer specialization and satisfaction, build technological competencies and achieve competitive advantage helping 'technology receiver organizations' to penetrate in new markets [38-39].

3.2.2 More usage by existing customers (MU)

Advance technology transfer may help organizations in introducing some features in their products/services such that customers currently using the products/services increase usage rate/frequency of use/want to keep multiple products [31].

3.2.3 End users support (EU)

The demand side often has heterogeneously mixed population with diverse demographic characteristics with scattered beliefs, preferences and ways of thinking [40]. There has been a part of society (testers/evaluators) that is eager to test newer technologies where as others (followers) decide acceptance of newer technologies based products/services on feedback by 'testers/evaluators' [41].

3.2.4 Market requirements (MR)

Various useful techniques; such as pre and post launch- questionnaire based surveys and interviews; may be conducted for surveying markets to help in perceiving, judging and suggesting market requirements [42].

3.2.5 Competition (CT)

To gain competitive advantage, it is important to take competition as guiding stick for perceiving, designing and manufacture products by implementing advance technologies [43-44].

3.2.6 Judgment about timing (JT)

Correct timing of withdrawing products manufactured using old technology and introducing new products with enhanced features and quality resulting by implementing advance technology may play an important role towards successful acceptance from customers [45].

3.3 Technical features (TF)

Ability of any organization to adopt advanced technology to realize expected benefits out of the technology adoption process may depend on existing technical and organizational capabilities [3, 46-47].

3.3.1 Scientific changes (SC)

Technological support level and technology management effectiveness may require necessary scientific changes [48] to bring about new products with distinct features and enhanced performance utilizing new technologies' successful implementation [49-51].

3.3.2 Technological abilities of suppliers (TS)

Technically able suppliers'/vendors' support may be referred as an important aspect of TT implementation process [52], which is necessary to transfer the technology to vendors/suppliers and maintain same level of technical competency throughout the supply chain [53].

3.3.3 Local suitability of technology (LS)

Suitability of given technology for adoption and adaptation may depend on: prevailing social, economic and environmental conditions of location of deployment; and management practices followed within a country/community [54].

3.3.4 Compatibility (CP)

Transferred technology should not be appropriate only to the customer's requirements, but it need to be adaptive to user's environment to contribute to provide healthy and reasonable growth and local environment development [55].

3.3.5 Functionality (FS)

Functionality increases success rate of technology transfer process by attracting customers [56-57].

3.3.6 Reliability (RL)

Technologically sound organizations may have higher demands of their products or services with attributes such as technical assistance, quality and reliability [22].

3.3.7 Trial-ability (TA)

It is necessary to gauge technology transfer process for its performances [58] and trial-ability is the degree to which an innovation/technology is applied or experimented on limited basis, to reduce uncertainty [59].

3.3.8 Observe-ability (OB)

Technology transfer process requires to produce improvements in business results, which need to be observed [58] and observe-ability is degree to which the results, outcomes and benefits of innovation/TT process implementation are visible to others diminishing uncertainty [59].

3.4 Regulatory concerns (RC)

Regulatory concerns including legislative framework may be one of most important critical factors to adopt TT and is often incentivized and supported by technology friendly policies; subsidies to enhance its usage; and sufficient training support [60-61].

3.4.1 Government authorities (GA)

Government authorities' support while framing regulations has been recognized as one of very useful enablers in the successful implementation of technology transfer process having an influence upon various enablers significantly influencing the process [3]; and if process of TT is supported by government, it may help in diminishing technological gap between foreign and local firms by establishing policies and systems encouraging R&D [62-63].

3.4.2 Environmental concerns (EC)

Environmental thinking of people of a nation may be established and supported by 'Green Governance'; and low-carbon development may not be successfully achieved without support of advanced technologies. Continuous efforts of 'green thinking nations' may augment investments in low-carbon technology towards determining technical possibility of achieving low-carbon technology transfer from developed nations to developed nations [64].

3.4.3 International bodies (IB)

The international community (including several collaborations of 'like thinking' nations and environment conscious bodies) should gear up process of negotiation of climate obligations [64]. International bodies and developed nations may come forward to grant support by funds through task-sharing and low carbon TT [63].

3.5 Managerial and strategic issues (MS)

The management approach and attitude towards changes may significantly influence TT performance [3], [65].

3.5.1 Strategic implications (SI)

Organization's development and use of appropriate technology may be managed effectively to support the organization's business strategy [66].

3.5.2 Personnel resources (PR)

Technology transfer process activities may involve knowledge that is, generic and specialized in nature; and embodied and reflected in employees' actions, interactions [67] and way of working.

3.5.3 Training and development support (TD)

Training, education and skill development are regarded necessary critical elements towards facilitating TT [68] by raising the skill level of employees including soft and technical skills (specialized and multi-disciplinary) and also, influential in seeking cooperation from the end users/customers in TT process [69-70].

3.5.4 Commitment (CM)

Management perception, visionary approach, commitment, leadership and support has been recognized as a vital key factor towards accomplishment of any project successfully by: having positive influence upon project communication that further has influence on cooperation at different levels [61]; and supporting actions to establish an infrastructure helpful to process of TT[3].

4. Research framework and methodology

Evaluation of critical factors of TT ranking problem has been dealt with Analytical Hierarchy Process (AHP). Twenty four Constructs of TT have been sorted from extensive review; validated from experts' opinions; and categorized in to five dimensions of CFs of technology transfer i.e. Relative advantage in economic terms, Marketing related benefits and forces, Technical features, Regulatory concerns and Managerial and strategic issues. Three experts were from academia and two from Indian manufacturing industry. Further, AHP methodology has been utilized to rank these CFs dimensions and constructs under each dimension. AHP framework of evaluation of technology transfer critical factors is structured that includes levels three in number: goal: To Prioritize Technology Transfer Critical Factors; Five dimensions of CFs of TT; and Constructs under each dimension of CFs. A Research frame work of evaluation of technology transfer critical factors has been shown in Fig. 2.

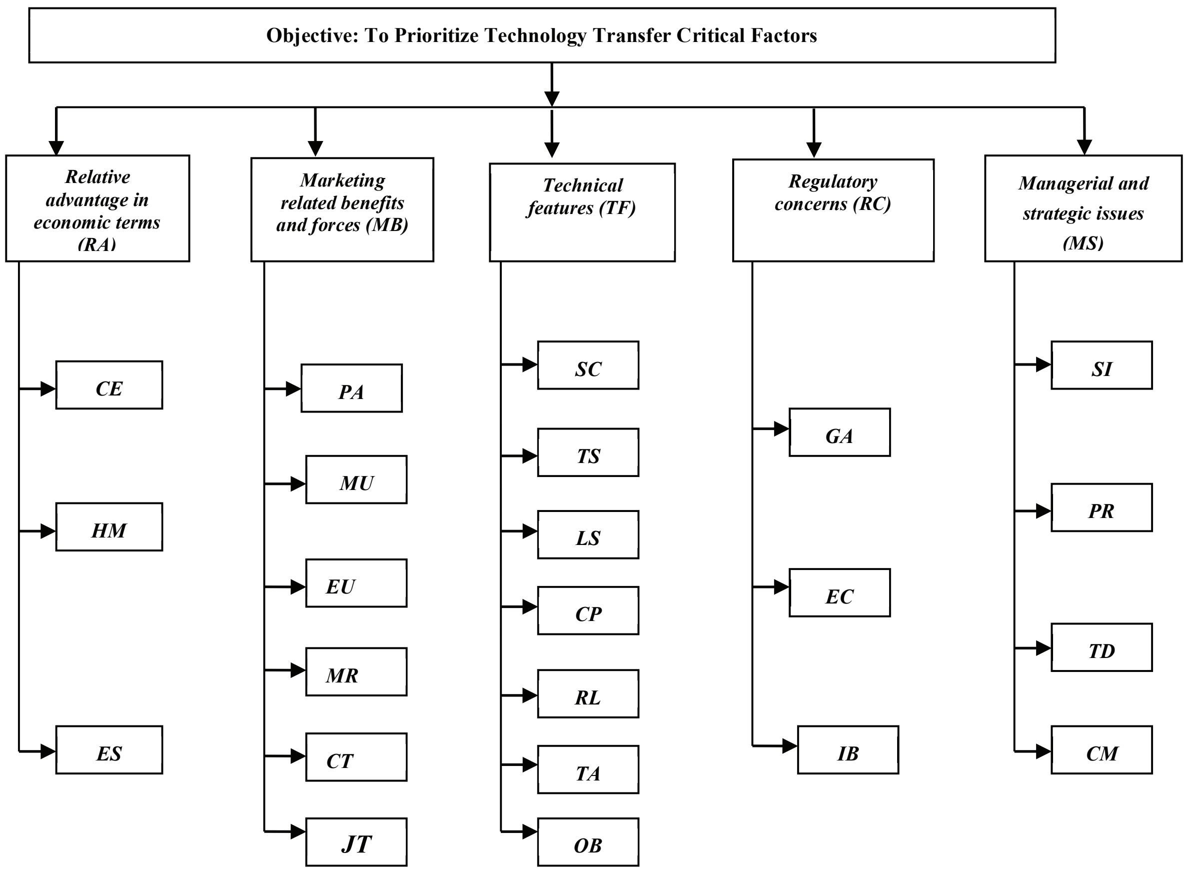

Fig. 2 - AHP based hierarchical model to evaluate technology transfer critical factors

4.1 AHP technique

AHP technique compares alternatives/criteria with reference to specified criterion, in pair wise manner and resulting final comparison matrix may be utilized to evaluate rank of alternatives to help in decision making process; and it has following three steps [71-74]:

- Establish structure (hierarchical in nature) with decision elements (Figure 1 shows hierarchical structure to evaluate CFs of TT);
- Construct pair wise comparison matrices (PWCMs)
- Calculate the consistency using Equation (1) and Equation (2).

$CI = (\lambda_{max} - n)/(n-1)$ ……. Equation (1)

$CR = CI/RI$ ……. Equation (2)

The value of RI depends upon the size matrix. Tables 1 shows values of RI for matrices of order (n) of 1 to 8 [72].

Table 1 –Random index.

N	1	2	3	4	5	6	7	8
R.I.	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Consistency ratio range (acceptable) varies as per the matrix size i.e. 0.05 for 3*3 matrix, 0.08 for 4*4 matrix and 0.1 for higher order matrices.

5. Data analysis and results

Based on the ratings obtained through expert's inputs, matrices are formulated and subsequent calculations for obtaining priorities are done using the methodology of AHP. Framework of AHP to evaluate TT critical factors is structured hierarchically that includes three levels: goal: valuate TT critical factors; In 2nd level, identified Five critical factors dimensions: Relative advantage in economic terms, Marketing related benefits and forces, Technical features, Regulatory concerns and Managerial and strategic issues have been analyzed for hierarchy. Table 2 shows Pair wise comparison matrix (PWCM) indicating weights provided by experts to dimensions.

Table 2–PWCM of criteria.

Criteria	RA	MB	TF	RC	MS	Priority Matrix	Rank
RA	1	2	2	1/3	2	0.19505	2nd
MB		1	1	1/5	1	0.10065	4th
TF			1	1/3	3	0.14384	3rd
RC				1	6	0.48159	1st
MS					1	0.07886	5th
Maximum Eigen Value =5.1386							
CI= 0.0346494							

From the analytical results shown in Table 2, "Regulatory concerns 0.48159" was the most important dimension of critical factor to technology transfer process followed by "Relative advantage in economic terms (0.19505)"; "Technical features (0.14384)"; "Marketing related benefits and forces (0.10065)" and "Managerial and strategic issues (0.07886)".

In the next level (3rd level) of decision making, various constructs in each dimension of critical factors of technology transfer process have been ranked for each dimension. Table 3 evaluates the constructs under dimension "Relative advantage in economic terms" had been checked for hierarchy.

Table 3–PWCM of relative advantage in economic terms (RA) dimension.

Constructs under RA	CE	HM	ES	Priority Matrix	Rank
CE	1	½	¼	0.14937	3rd
HM		1	2	0.47423	1st
ES			1	0.37639	2nd
Maximum Eigen Value = 3.21736					
C.I.= 0.108681					

'Higher margins of profit (0.47423)' had been reported most important constructs in "Relative advantage in economic terms", followed by 'Expected increase in sales (0.37639)' and 'Cost effectiveness (0.14937)' in Table 3.In Table 4, constructs under dimension "Marketing related benefits and forces" had been checked for hierarchy.

Table 4–PWCM of marketing related benefits and forces (MB) dimension

Constructs under MB	PA	MU	EU	MR	CT	JT	Priority Matrix	Rank
PA	1	2	1/5	1/5	1/2	1	0.09656	4th
MU		1	½	½	1/2	1/4	0.07617	5th
EU			1	1	1	1	0.22715	1st
MR				1	1	1	0.22715	1st
CT					1	1	0.18216	3rd
JT						1	0.19082	2nd
Maximum Eigen Value = 6.43807								
C.I.= 0.0876146								

'End user support (0.22715)' and 'Market requirements' had been reported the most important construct in "Marketing related benefits and forces" critical factor to technology transfer, followed by 'Judgment about timing (0.19082)'; 'Competition (0.18216)'; 'Penetration in new areas (0.09656)' and 'More usage by existing customers (0.07617)' as shown in Table 4.Constructs under dimension "Technical features" had been checked for hierarchy in next table.

Table 5–PWCM of technical features (TF) dimension

Constructs under TF	SC	TS	LS	CP	FS	RL	TA	OB	Priority Matrix	Rank
SC	1	1	½	¼	1/3	1/3	1/2	½	0.05843	8th
TS		1	1	1	1	1/3	1/2	½	0.08598	7th
LS			1	2	1	1/2	1	1	0.12515	5th
CP				1	½	1/2	1/2	½	0.09505	6th
FS					1	1	1	1	0.14490	3rd
RL						1	2	2	0.21353	1st
TA							1	2	0.15054	2nd
OB								1	0.12643	4th
Maximum Eigen Value = 8.36405										
C.I.= 0.0520074										

Table 5 shows that 'Reliability (0.21353)' had been found the most important construct in "Technical features" dimension of critical factor to technology transfer, followed by 'Trial-ability (0.15054)'; 'Function-ability (0.14490)'; 'Observe-ability (0.12643)'; 'Local suitability of technology (0.12515)'; 'Compatibility (0.09505)'; 'Technological ability of suppliers (0.08598)' and 'Scientific changes (0.05843)'.In Table 6, constructs under dimension "Regulatory concerns" had been checked for hierarchy.

Table 6–PWCM of regulatory concerns (RC) dimension

Constructs under RC	GA	EC	IB	Priority Matrix	Rank
GA	1	1	½	0.24022	2nd
EC		1	1/3	0.20984	3rd
IB			1	0.54994	1st
Maximum Eigen Value = 3.01829					
C.I.= 0.00914735					

From the analytical results shown in Table 6, 'International bodies (0.54994)' construct had been evaluated the most important in "Regulatory concerns", followed by 'Government authorities (0.24022)' and 'Environmental concerns (0.20984)'.In the next table, under dimension "Managerial and strategic issues" had been checked for hierarchy.

Table 7–PWCM of managerial and strategic issues (MS) dimension

Constructs under MS	SI	PR	TD	CM	Priority Matrix	Rank
SI	1	½	1/2	1/4	0.10518	4th
PR		1	1/2	1/2	0.18181	3rd
TD			1	1/3	0.23517	2nd
CM				1	0.47784	1st
Maximum Eigen Value = 4.11794						
C.I.= 0.0393141						

Table 7 shows that 'Commitment (0.47784)' has been found the most important construct in dimension "Managerial and strategic issues" to technology transfer, followed by 'Training and development support (0.23517)'; 'Personal resources (0.18181)' and 'Strategic implications (0.10518)'.

It is important to infer here that values of consistency ratio are in acceptable range for various PWCMS shown in Table 2 to Table 7, ensuring reliability of decision-makers [19-20].

6. Discussions of findings

Technology transfer may help organizations and supply chains towards innovation of new and better performing products, processes/activities, services and practices leading to increased efficiency and effectiveness, greater market share and increased profits. It may be useful for small and medium enterprises (SMEs) due to their size and resource constraints; however, a need has been felt for transfer of newer technologies in order to compete, and in fact, this need for transfer of newer technologies has created newer niche-market for TT [75]. In fact, increasing trend of adoption of TT is being recognized as one of rationale potential for enhancing business competitiveness of SMEs in their efforts towards globalization [17].This paper provides identification and evaluation of critical factors of effective technology transfer process in Indian perspective. Twenty four CFs have been segregated from literature review and categorized in to five dimensions. Further, AHP methodology has been appropriately utilized for evaluation of CFs of technology transfer.

- 'Regulatory concerns' has been found the most important dimension of critical factors to technology transfer process followed by 'Relative advantage in economic terms'; 'Technical features'; 'Marketing related benefits and forces' and 'Managerial and strategic issues' in descending order. In fact, intellectual property rights need to be protected to enhance technology sharing towards TT implementation through: improved the legal framework (at national and international level) and support; managing technical personnel and establishing intangible assets evaluation system; efficient reward system establishment; consistent technology development which has been shared by Jianna and Jie (2011) [76].
- Further, under each dimension, CFs have been analyzed for hierarchy. In 'Regulatory concerns' dimension, 'International bodies' CF has been found as the most important and 'Environmental concerns' least important CF to implement technology transfer.
- Similarly, 'Higher margins of profit' has been shown as most important CF and 'Cost effectiveness' as least important CF in 'Relative advantage in economic terms' dimension.
- 'Reliability' has been found the most important CF and 'Scientific changes' as least important CF in 'Technical features' dimension of critical factors of technology transfer.
- Further, in 'Marketing related benefits and forces' dimension of CFs, 'End user support' and 'Market requirements' have been reported as most important CFs and 'More usage by existing customers' has been reported as least important CF. Customer is most important central element considered while dealing with various managerial activities of any business. Manufacturers may offer their improved products' and processes' technologies, and management; to provide better valued products and services to satisfy existing customer needs and attract new customers; and explore new markets [77].
- In dimension 'Managerial and strategic issues', 'Commitment' has been found as most important CF and 'Strategic implications' as least important CF to technology transfer.

Based upon rankings of 'critical factors of technology transfer (twenty four) and dimensions (five)', and 'subsequent discussions with experts'; a conceptual model of TT critical factors and dimensions has been formulated, which has been presented in Fig. 3. Ranking of each dimension has been abbreviated as 'R_i', where 'i' varies from 1 to 5; and ranking of each CF has been shown as 'R_{pq}', where 'p' represents ranking of respective dimension under which that CF has been categorized and 'q' represents the CF's ranking.

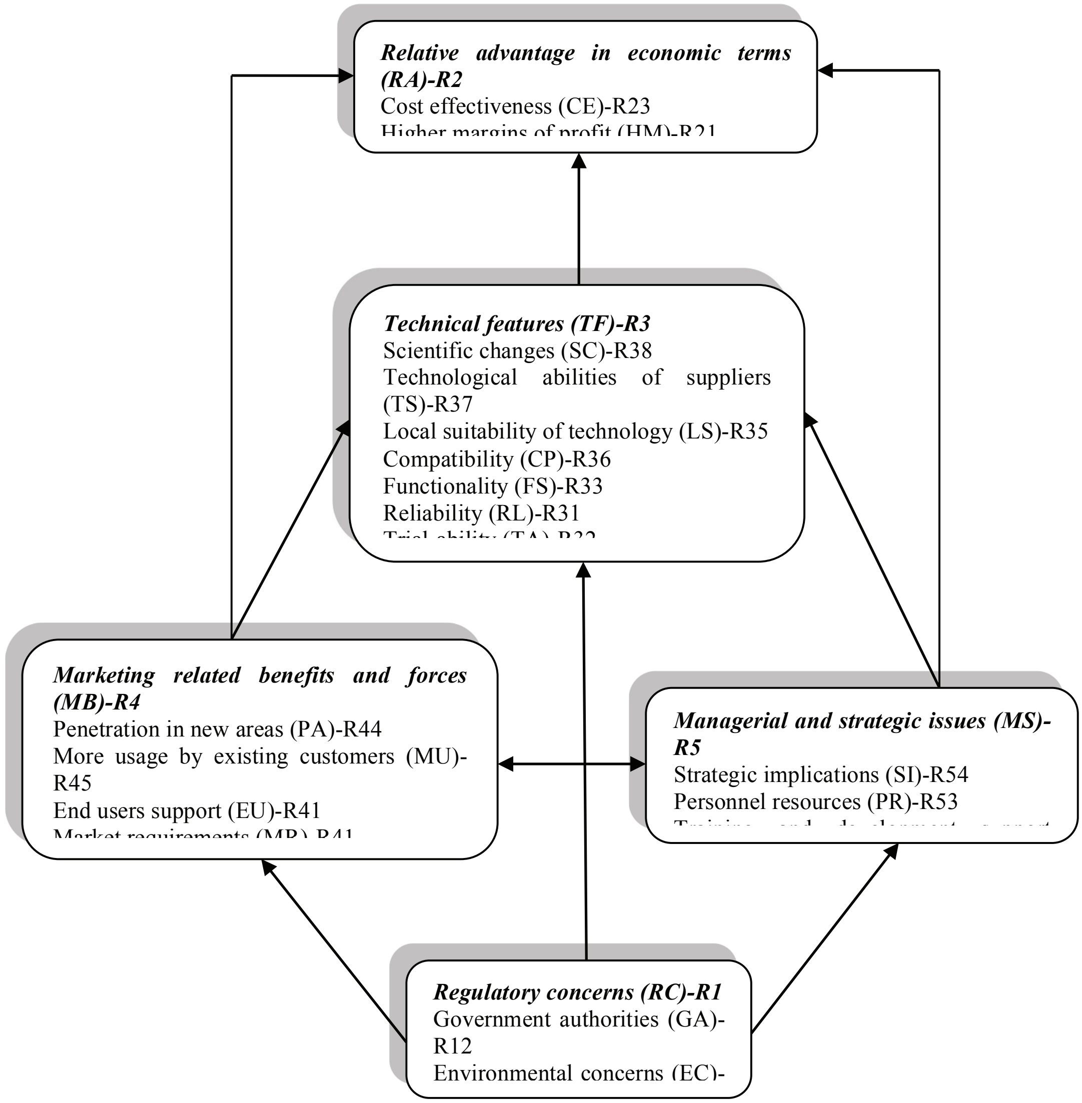

Fig. 3 - Conceptual model of technology transfer critical factors

Authors further propose to evaluate overall weight of each CF by considering local weight of CF and multiplying it by respective global dimension's weight. After calculating these overall weights of CFs, these have been tabulated in Table 8, which shows that 'International bodies', 'Government authorities' and 'Environmental concerns' have been rated top three most important critical factors in totality based upon overall weight values of CFs.

Table 8–Calculation and ranking of overall weight of CFs of technology transfer

Dimension S. N.	Dimension of CFs of TT	Final weight of the dimensions	Rank	CFs S.N.	Identified CFs of technology transfer	Local weight of CFs	Overall weight of CFs	Overall ranking of CFs
1	Relative advantage in economic term	0.19505	2nd	1.1	CE	0.14937	0.02914	8th
				1.2	HM	0.47423	0.09250	4th
				1.3	ES	0.37639	0.07341	5th
2	Marketing related benefits and forces	0.10065	4th	2.1	PA	0.09656	0.00972	20th
				2.2	MU	0.07617	0.00767	23th
				2.3	EU	0.22715	0.02286	9th
				2.4	MR	0.22715	0.02286	9th
				2.5	CT	0.18216	0.01833	14th
				2.6	JT	0.19082	0.01921	12th
3	Technical features	0.14384	3rd	3.1	SC	0.05843	0.00840	21th
				3.2	TS	0.08598	0.01237	19th
				3.3	LS	0.12515	0.01800	16th
				3.4	CP	0.09505	0.01367	18th
				3.5	FS	0.14490	0.02084	11th
				3.6	RL	0.21353	0.03071	7th
				3.7	TA	0.15054	0.02165	10th
				3.8	OB	0.12643	0.01819	15th
4	Regulatory concerns	0.48159	1st	4.1	GA	0.24022	0.11569	2nd
				4.2	EC	0.20984	0.10106	3rd
				4.3	IB	0.54994	0.26484	1st
5	Managerial and strategic issues	0.07886	5th	5.1	SI	0.10518	0.00829	22th
				5.2	PR	0.18181	0.01434	17th
				5.3	TD	0.23517	0.01855	13th
				5.4	CM	0.47784	0.03768	6th

7. Implications of the research

We attempted to: identify critical factors to implement technology transfer successfully; analyze importance of CFs by applying AHP technique; present conceptual model by incorporating experts' suggestions and recommendations. Here we propose a framework involving role players, expected role, role performance, role performance measures and action plan for understanding about benefits/applications/learning out of this proposed strategic framework. Table 9 presents in brief strategic framework for technology transfer process implementation.

Table 9–Strategic framework for technology transfer process implementation

Consideration	Benefits/Applications/Learning
1. Critical factors	Managers/ practitioners may be able to identify which CFs are affecting TT process and what may be the benefits coming out of the same, they should concentrate in managing these factors
2. AHP ranking	On the basis of AHP Ranking obtained for each CF, the importance level can be judged for each CF.
3. Conceptual model level	This can be used for better understanding of interactions among requisites and benefits of product innovation management process
4. Role players	Vital to specify who is going to manage which CF, help in identifying organisational structure for effective TT
5. Expected role	Roles to be specified to different associated players
6. Role performance	Different role players can be monitored with their role performance. This can be compared with expected performances.
7. Role performance measures	These measures may help in identifying the level of improvement. Measures can be in terms of financial ratios, subjective or objective benchmarks.
8. Action plan	Based on the expected performance an action plan may be developed for technology transfer. A clear plan so developed may be helpful to streamline the associated systems.

Table 10 has been further presented to address appropriately the strategic framework elements (critical factors to implement technology transfer, AHP rankings of TT CFs, conceptual model, which CF will help to achieve which CF/s, observations on findings, role players, expected role, role performance, role performance measures and action plan.

Table 10–Practical and strategic implications

S. No.	TT CFs dimension	Rank	Level in model (bottom to top)	CF will help to achieve	Practical implications on					
					Observation/s	Role player	Role expected	Role performance	Role performance measures	Action plan
1.	Regulatory concerns	1st	I	• Marketing related benefits and forces • Managerial and strategic issues	Bottom most, driving factor and will have significant role in driving TT	• Government authorities • International bodies/authorities • Environment concerning bodies	Provision of regulations and guidelines to facilitate technology transfer with a concern for environment and society	Formulation and provision of appropriate regulations and guidelines for technology transfer	Numbers of regulations and guidelines	This CF needs to be tackled and managed maximum
2.	Marketing related benefits and forces	4th	II	• Managerial and strategic issues • Technical features	Sharing same level with 'Managerial and strategic issue'; Human factor identified as important	• Customers • Marketing and sales force • Competitors • Advertisers • Marketing/advertizing supporting firms	Providing Marketing system	Developing voice of customers	Nos of Technologies as per demand of customers; Increased usage of existing products/services; New customers attracted	Develop a plan towards effective marketing & enhanced sales
3.	Managerial and strategic issues	5th	II	• Marketing related benefits and forces • Technical features	Sharing same level with 'Marketing related benefits and forces'; Human factor identified important	• Top Management • HR personnel • Strategic managers and staff • Training and development staff • TT implementing staff • Outside agencies involved in TT and training	Team building and liaison with external agencies; Training and development; Appropriate & prompt strategies formulations and appraisal; Strengthening human resource; Committed organization culture development	Providing assistance in developing different strategic plans and policies	In terms of financial ratios or other measures of judging Firms performance	Develop strategic and tactical plans

4.	Technical features	3rd	III	• Relative advantage in economic term	Important to achieve relative advantages	• All technical staff • All shop floor employees • R&D supporting staff • All suppliers • TT agents • Outside technical and R&D agencies	Training throughout the supply chain; R&D activities for appropriate scientific changes; Evaluating local suitability of technology; Evaluating compatibility, functionality, reliability, trial-ability and observe-ability	Providing assistance to R& D and shop-floor persons	How many features are taken care of	Improving the technical features as per requirements
5.	Relative advantage in economic term	2nd	IV	• This CF is final outcome and forma the top most level of conceptual model	Top most dependent outcome	• All stake holders	Maintaining the relative advantages	Putting consistent efforts to sustain and enhance relative advantages	Benefit to cost ratio; Increase in sales; Increase in profits	Maintain relative advantages towards achieving competitive edge over competitors

The research findings, consequent discussions and implications may be helpful in obtaining strategic action plan to manage technology transfer process implementation effectively and efficiently getting benefited. Fig. 4 shows the deduced strategic action plan as gist of the research work that may be helpful to industry practitioners/TT strategic managers/policy planners to: identify, understand and prioritize responsible critical factors of technology transfer process; and analyze which CF they have to improve upon for making organizations and supply chains benefited from successful TT process implementation. Leadership may see what needs to be done to achieve the goals.

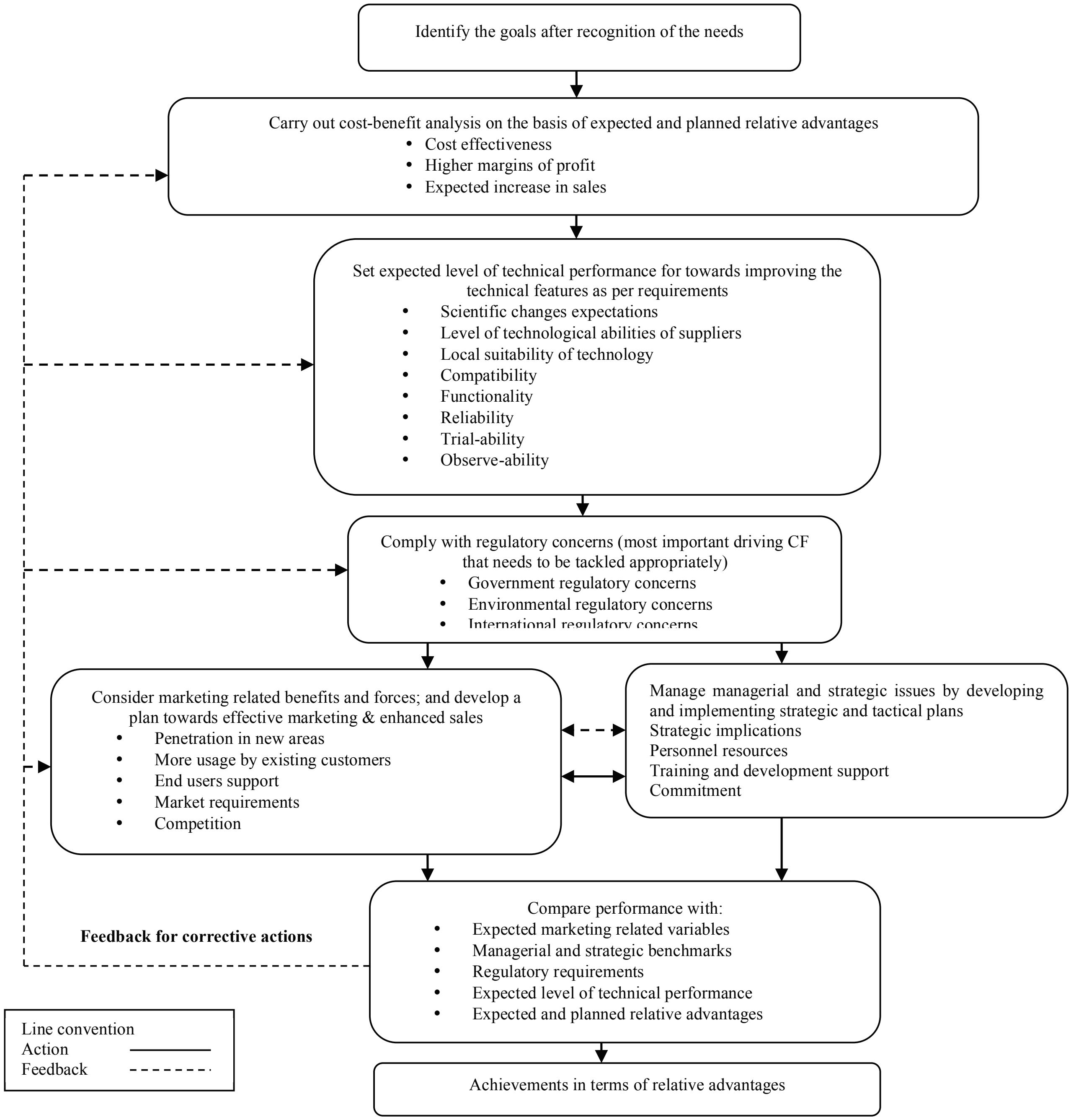

Fig. 4 - Strategic action plan for technology transfer implementation

This paper has some unique contributions, which are given as:

- This study identified twenty four CFs and five dimensions related to technology transfer. The listed constructs and dimensions of TT will enable to improve the implementation of TT within any organization.

- The work proposes a model to evaluate factors in TT implementation using AHP approach. The proposed AHP based model is useful in evaluating the TT implementation success factors.

8. Conclusions, limitations and scope for future work

Technology transfer has been recognized as an approach of high utility for gaining competitive advantage over other organizations/supply chains; and a recent and relevant research area in developing countries. Developing countries like India may be benefited from TT, mainly because the recipient countries grasp know-how, expertise, and skills for implementing and operating the technology towards becoming capable of developing newer production capacities [78]. In this study, a task has been attempted to sort, evaluate and analyze critical factors towards effective technology transfer in Indian perspective. Literature review approach and expert's inputs has been utilized to identify CFs for effective technology transfer. Idea engineering workshop has been conducted to make pair wise comparison of identified dimensions and CFs to calculate: weight/ranking of five dimensions under which twenty four CFs have been categorized; and local and global/overall weight/ranking of each CFs using an appropriate and established methodology-Analytical Hierarchy Process. Important observations have been made:

- ‘Regulatory concerns’ observed as most important dimension indicating significance of appropriate legal and regulatory framework adoption and support at National and International level.
- ‘International bodies’; ‘Higher margins of profit’; ‘Reliability’; ‘End user support’ and ‘Market requirements’; and ‘Commitment’ have been identified highest rated CFs in their respective dimension considering local weight of CF.
- ‘International bodies’ has been rated most important top ranked (overall) critical factor based upon overall weight value.

Practical and strategic implications have been provided followed by strategic action plan presented pictorially. We believe that this research work may be served as foundation for extending research in area of technology transfer especially in developing countries such as India.

In this paper, an attempt has been made to rank the critical factors of for effective technology transfer and following limitations have been reported [79]:

- AHP relies on experts' opinions and opinions of experts may be prejudiced.
- AHP matrices have been formed by the ratings obtained by experts during an idea engineering workshop, where experts were not random selected.

Above limitations of experts' opinion biasness may be overcome by utilizing opinions of bigger group of experts and then applying some appropriate statistical tool/s.

The following are some research directions suggested for future research based on this work:

- ✓ Structural equation modeling technique may be applied further to test validity of presented ISM based model. To know present status of product innovation in a real world case, SAP-LAP analysis [80-81] may be another future direction. Interpretive Ranking Process may be used [82-83] to rank requisites of product innovation management with respect to expected performance outcomes. Contextual interactions among these identified requisites may be further analyzed using Contextual Interactions Analytic Hierarchy Process (CIAHP) methodology suggested by Kumar et al. (2014) [84].
- ✓ DEAMATEL methodology may be utilized for categorizing CFs (according to their priority) into cause and effect group [85].
- ✓ To avoid problems of vagueness, uncertainties and the subjectivity associated with human judgment, triangular fuzzy numbers may be combined with this methodology as suggested by Mangla et al. (2015) [86].
- ✓ Normally, Multi-criteria Decision Making (MCDM) methodologies may be considered as changeable and imprecise. Sensitivity analysis may be applied to evaluate impact of ratings provided by experts and demonstrate the robustness of the adapted methodology.
- ✓ Some other multi-criteria decision making techniques like TOPSIS, ANP etc. may be utilized for similar problems and their results may be further compared.

Further, appropriate case studies may be suitably analyzed by following the strategic action plan; and comparing the performances in terms of performance measures (suggested for each stage) to the cases (where the strategic action plan were mot followed), in order to validate the findings and usability of recommendations.

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