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Abstract

Purpose – Technology transfer becoming an important area especially in developing and less developed countries. The purpose of this paper is to address issue of supply chains' benchmarking based upon their capability to mange technology transfer critical barriers mitigation efforts toward making technology transfer process implementation successful.
Design/methodology/approach – The present paper is based on two research stages. Initially, extensive literature review has been made to identify critical barriers. In total, 20 technology transfer critical barriers have been identified from literature review and categorized in to six criteria. In second stage, analytics hierarchy process has been utilized to rank the critical barriers of technology transfer in supply chain and provide a benchmarking framework.
Findings – Political barriers (PB) have been analyzed most significant criteria of critical barriers to technology transfer followed by socio-cultural barriers (SO) and economic barriers (EB). "Political instability," "Difficulty in transfer and diffusion," "Too expensive," "Inappropriate/incompetent technology and resource wastage in technologies imported," "Inactive role of SC members and resistance to change" and "Management attitude" have been found most hindering barrier in their respective category/criterion of technology transfer barriers.
Research limitations/implications – Scope of the present study has been limited to propose framework to benchmark supply chains by analyzing 20 critical barriers of technology transfer grouped in to six dimensions using analytical hierarchy approach based on "ratings provided by experts," which may be biased.
Practical implications – Benchmarking process has been proposed to calculate value of total of overall weights to a particular supply chain named as "Technology Transfer Barriers Mitigation Index (TTBMI)" useful to present capability of supply chains to manage technology transfer barriers by a single numeric value. From "provider" developed county's view point, present benchmarking framework may be further applied to compare developing countries' ability to absorb and diffuse new technology.

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Originality/value – Benchmarking procedure has been dealt with using well-established methodology- analytical hierarchy process toward providing single numeric value index (TTBMI) indicating ability of supply chains to manage/mitigate technology transfer barriers.

Keywords Benchmarking, Analytical hierarchy process, Supply chains, Critical barriers (CBs), Indian manufacturing industry, Technology transfer

Paper type Research paper

1. Introduction

Organizations have been adopting advance technologies to meet existing challenges toward new/better products, processes/activities, services and practices for delivering higher efficiency and effectiveness. Technology may be referred to any one or combination of tool, technique, material, skill, capability, organizational structure and applied knowledge (Khalil, 2000). Technology transfer may be defined as the transfer of new knowledge, products or processes from one organization to another for achieving business benefits (such as higher sales volume, lesser costs involved, higher profits and enhanced brand image, etc.) and competitiveness (Wittamore *et al.*, 1998; Lee *et al.*, 2012). 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 (Davenport, 2013). Wong *et al.* (2003) emphasized to utilize foreign partner's competitive advantage and domestic partner's unique knowledge in the process of transfer of technology from the foreign partner to the domestic partner. Li-Hua (2006) addressed the appropriateness and effectiveness of TT process important for economic development by using structured survey and analysis; whereas, Al-Mabrouk and Soar (2009) used Delphi-type survey to identify, analyze and discuss major issues for successful information technology (IT) transfer in Arab countries and presented master set of ten major issues categories for successful IT transfer. Ille (2009) proposed development of brand image using various marketing TT after examining different strategies to build global brands for improving export capabilities. Ustundag *et al.* (2011) investigated causal relationships among four factors influencing technology transfer officers' (TTOs') performance using fuzzy cognitive maps, and findings suggested that TTO performance is mainly influenced by: two external factors – economic uncertainty and industry research demand; and two internal factors – R&D budget of university and TTO human resources capacity, and further suggested that TTO managers should focus on three performance measures (number of patents awarded, license income and number of established spin-offs) affected mostly by the internal factors. Banwet and Deshmukh (2010) identified ten success factors (Clear R&D vision and strategic directions; top management commitment; resources availability; R&D project management skills; organization culture and human resource focus; continuous monitoring of techno market monitoring environment; teamwork; knowledge networks; customer focus and market orientation; and performance of national R&D organizations) for improving Indian R&D organizations' performance by using interpretive structural modeling (ISM) and indicating "Clear R&D vision and strategic directions" as most driver success factor and "Performance of national R&D organizations" as top dependent success factor in ISM based hierarchy statistically validated through structural equation modeling. Similarly, Mohamed *et al.* (2012) determined key factors of TT performance using structural equation modeling, exploratory factor analysis and confirmatory factor analysis in a study involving modeling the TT process in the petroleum industry of

Libya and suggested government support factor (government support, laws and regulations, petroleum industry strategy, international quality standards and IT) and technology learning capability factor (supervision, adoption, teamwork, absorption, training, technology complexity and industry knowledge) to be the key predictors of TT performance to the Libya's petroleum industry. Kaushik *et al.* (2014) provided an overview of literature on various TT implementation issues and proposed TT conceptual model. An extensive literature review was used to identify enablers and barriers of technology transfer. In total, 17 barriers in the technology transfer process implementation. Findings suggested that TT process is not easy due to existence of many barriers and much research is needed to remove these barriers to implement TT in most effective and efficient way.

Technology transfer yet have not received due attention to explore some important issues in development policy in most of developing countries (Kumar and Siddharthan, 2013). This may be attributed to existence of several types of barriers to technology transfer (Kumar *et al.*, 2014a). Technology transfer processes differ regarding barriers inhibiting the transfer process and barriers to technology transfer may vary across countries (Gilsing *et al.*, 2011). Being technology transfer one of the most fundamentally complex process of learning, effective transfer may not be possible until all the factors (helpful known as "enablers" and hindering termed as "barriers") related to this transfer process are well-explored and understood (Singh and Abhishek, 2013). Barriers to technology transfer may also be viewed as opportunities for intervention so that technologies may reach their full potential (Sathaye *et al.*, 2001). A good technology transfer can enable an organization to improve manufacturing productivity, alliance efficiency and adaptability, international expansion, and sustainable competitive advantage (Lee *et al.*, 2010). The problem areas identified gave direction to carry out the present research. Therefore, the objectives of the research are to:

(1) identify critical barriers hindering effective technology transfer process;

(2) prioritize critical barriers hindering effective technology transfer process, which will help practitioners toward directing mitigation efforts to make technology transfer process implementation effective and fruitful; and

(3) benchmark supply chains by analyzing technology transfer critical barriers.

Literature review approach has been adopted for identifying relevant critical barriers for effective technology transfer process. A literature review is an integral part of any research to identify the conceptual content of the field and gives guidance toward theory development (Luthra *et al.*, 2014a). In present research, it is suggested to use an AHP approach for prioritizing the critical barriers and benchmarking supply chains for effective technology transfer process by taking a case example. AHP, as a multi-attribute flexible decision support tool was first developed and applied by Saaty in 1977. The AHP methodology uses a multilevel hierarchical structure of objectives, criteria, sub criteria and alternatives, in a natural, pair wise mode (Saaty, 1980, 1994, 2000, 2008). The resultant may be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice (Saaty, 2008; Kumar *et al.*, 2009).

1.1 Organization of the paper

The remainder of this research paper has been organized as: review of relevant literature has been presented in Section 2; Section 3 explains methodology of the research; analysis of data and results have been presented in Section 4; finally, discussions have been given in Section 5 followed by concluding remarks with limitations of study and important directions for future research.

2. Literature review

Effective technology transfer is hindered by some barriers especially in developing countries. Therefore, most critical barriers should be identified and eliminated for effective technology transfer. To accomplish this task of identifying critical barriers to effective technology transfer process, literature survey was conducted by searching various key words like barriers of/to technology transfer, barriers hindering technology transfer, pressures to technology transfer. Google search; Google scholar; Emerald, Science Direct and other databases have been used for collecting supporting literature on critical barriers. Identification of the critical barriers of TT has been conducted in two steps. First, conducting a critical review of literature helped in identifying 20 critical barriers of TT. Second, identified TT CBs were validated from experts' (from academia and industry) opinions. For this, we conducted one day workshop in March, 2014, in which invitations were sent to 15 academicians and ten industry professionals. Out of 25 experts, four experts (two experts from academia and two from manufacturing industry) attended the workshop. In, one day idea engineering workshop (two sessions), the experts invited formed the decision group to share their judgments on barriers that are critical to hinder technology transfer practices. In the first session of workshop, identified barriers were confirmed for their utility and after long brainstorming session, identified 20 critical barriers were classified into six criteria (technological, managerial, socio-cultural, political, economic and supply chain barriers) through experts' judgments based upon their similarity. In second session, experts were asked to rate the identified criteria and critical barriers, other details regarding data collection have been provided in Section 4. These identified criteria and critical barriers have been detailed as follows.

2.1 Technological barriers (TB)

Innovations (using new technologies) need to compete with existing technologies (embedded in a well-functioning large technological system) (Negro *et al.*, 2010) and technical difficulty during the processes may be identified as barrier to implement TT (Chen and McQueen, 2010). Four TB have been identified and explained.

2.1.1 Complexity (CL). The TT process includes many complex matters such as: legal issues involving inter and intra country legislation complexities; technical complexities; financial calculations for feasibility; and marketing issues (Lipinski *et al.*, 2008). Higher complexity associated with a transfer process is one of important reasons hindering adoption of advance technologies.

2.1.2 Lack of IT enablement, IMS and effective communication (LI). IT may play key role during the process of technology transfer toward establishing a global knowledge-sharing culture and efficient communication (Pan and Leidner, 2003). Effective communication is very important as it serves the basic functions in managing organization and in some cases; lack of effective communication may also lead to the failure of IT implementation as users don't have clear information about their contribution, roles and the achievements (Habib, 2009; Luthra *et al.*, 2014b). In many developing countries public capacity for information dissemination is lacking and is seen as a major barrier for technology transfer (Talaei *et al.*, 2014).

2.1.3 Non-availability of skilled labor (NL). Lack of skilled workforce, experienced personnel, engineers, managers indicates directly or indirectly toward: inadequate infrastructural provisions for local education and training (Karani, 2001); and difficulties in understanding know-how about new technologies. In fact, educational infrastructure toward developing "skilled human capital" is the basic component facilitating for a successful TT (Choi, 2009). Lack of sufficient training on skills and know-how in SMEs (small and medium scale enterprises) has often been observed in TT projects (Shujing, 2012).

2.1.4 Inappropriate/incompetent technology and resource wastage in technologies imported (TI). For the developing economy there may be always some conflict over the choices: to become a country known for its mastery of appropriate technology; and to stay in the race to be world's best-practice technology adopter (Greenhalgh, 2013). There have been evidences in the wrong technology choices for combination of: lack of skills and capabilities of entrepreneurs; and lack of technical knowledge as among most valid reasons for failure (Jacobsson, 2008; Negro *et al.*, 2010).

2.2 Managerial barriers (MB)

Government organizations may have a tendency to import technologies, which may be developed easily domestically, due to low or no participation of practicing technology managers in process of "import decision making" by government authorities; however, decision makers need to be qualified skilled personnel to efficiently evaluate and analyze pros and cons of technologies proposed to be imported (Seong-Ho, 2012).

2.2.1 Management attitude (MA). PositiveMA may play an important role and greatly influence the transfer of appropriate technology from provider organization/country because of their key position in decision making process (Le Grange and Buys, 2002; Kumar *et al.*, 2014b).

2.2.2 Lack of timeframe (LT). The process of technology transfer has to be time bound to draw advantage and timeframe should be clearly specified and acknowledged before the start of implementation phase, According to one study, R&D subsidies were granted for limited period of time; and market stimulation programs were carried out inconsistently mainly due to technological disappointments and wrong judgments of timeframes leading to attention shifts (Negro *et al.*, 2010).

2.2.3 Inefficient management of R&D activities (IM). R&D infrastructure and competencies have been identified as an important determinant in TT (Verbano and Venturini, 2012); and in developing countries, investments which are made on R&D have not been found sufficient as compared to that in developed countries (Seong-Ho, 2012).

2.2.4 Attitude of employees (AE). Many organizations' cultures have been characterized by "not-invented-here" tendencies of employees reluctant to acquire technology from external sources (Lichtenthaler *et al.*, 2011); however, having staff with positive attitude may help organizations to maintain positive thinking toward activities and processes in managing change (Aziz *et al.*, 2012; Luthra *et al.*, 2014c).

2.3 Socio-cultural barriers (SO)

Technology development and transfer process need to be social process matching with "need patterns" of economically challenged sector of society; and its success may be highly dependent upon the socio-cultural impacts (Ho and Lau, 1998; Kedia and Bhagat, 1988). Absence of social and cultural support may be identified as important barriers to implement TT (Doukas *et al.*, 2009).

2.3.1 Difficulty in transfer and diffusion (DT). Technology development should be carried out considering all factors and issues related to targeted segment of prospective customers exhibiting pre and post purchase behaviors according to their prevailing social and cultural system; so that transfer of new products/services and adoption take place smoothly without any conflicts (Homburg, 2011).

2.3.2 Inefficient societal/cultural judgment (IJ). The effectiveness of technology transfer is highly dependent upon efficient judgment about variations in societal cultures; and partners from different cultures may experience difficulties in interaction and other relevant cross-cultural problems at start and during TT processes (Hirt, 2012).

2.3.3 Insufficient data (ID). Sufficient data, primary and secondary, should be arranged and appropriately synthesized and then analyzed to; compare money inflow and outflow; evaluate current personnel and resource allocations appropriateness (West, 2012); understand need and wants of customers; and analyze whether proposed products/services matches with their socio-cultural scenario.

2.4 Political barriers (PB)

Innovative technology transfer may need political astuteness, commitment and credibility in effective management of projects (Markham, 2000; Walter *et al.*, 2011); and there should be political desire at the highest levels of both the countries (provider and receiver) for supporting R&D activities, financing and delivery mechanisms (Castells, 2005).

2.4.1 Inactive role of change agent (IR). Agent is one of important actors playing significant role especially to ensure successful international technology transfer implementation process from initiation phase (including finalizing specifications and calling tenders, etc.) till "handing over" officially (Proto *et al.*, 2012).

2.4.2 Lack of collaboration between government and research institutions (LG). It has found that there has been lack of collaborative research between government and research institutions especially in developing countries (like India) (Kirkland, 1996). Also, Cetindamar (2001) found regulations and public pressures are main determinants in transfer and diffusion of environment technologies in a case study, indicating toward importance of regulations to nurture more and more collaborative research programs and alliances between government and institutions.

2.4.3 Political instability (PI). Regional conflicts or local PI may be observed as main obstacle to transferring technology and affects the materialization of relevant projects (Chaaban and Akkawi, 2013). Hence, PI in developing countries, leading problems in enforcing policy, may be considered as one of the political barriers (Shujing, 2012).

2.5 Economic barriers (EB)

Lack of finance and expertise has been found valid and significant barriers in a study based on two surveys to explore the existing linkages between Bolivian universities and the renewable energy sector (Gottwald *et al.*, 2012).

2.5.1 Too expensive (TE). Organizations and supply chains require high costs in order to stay up-to-date and to manage collaborative projects; and these high costs for technology/knowledge transfer and absorption inter and intra organizations/supply chains/countries may form a barrier (Gilsing *et al.*, 2011).

2.5.2 Lack of funds (LF). For developing countries, new technologies have been perceived expensive and risky comparing with existing technologies (Van der Gaast *et al.*, 2009) and may face problem of "lack of funds" to aid TT (Shujing, 2012).

2.5.3 Uncertainty of recovery (UR). Every decision of technology transfer investment may have various possibilities of outcomes identified with certain uncertainty known as investment risk (Liu *et al.*, 2010) and many programs of TT may fail to acknowledge the need for long-term financial security and cost-recovery by investors (Forsyth, 2005). Recovery may require establishing new level of management and intervention (Forsyth, 2010).

2.6 Supply chain barriers (SC)

Supply chain members, including suppliers/vendors, distributors, retailers and customers, may have certain barriers putting pressure on parent firm to implement new technology throughout the SC and links between customers and SC are often narrow in their scope focussing on technical knowledge transfer (Barson, 2000).

2.6.1 Current products meeting the needs (CP). Prospective customers, mainly from the "follower" group of people that start using the product/services after "tester" group of users, may be hesitating or sometimes reluctant to test and then accept products and services offering some of new features utilizing new technology when existing products/services are meeting minimum expected requirements (Storey and Salaman, 2009).

2.6.2 Inactive role of SC members and resistance to change (RC). Managing change may play important role in collectively moving toward technology change taking all SC members together helping in successful conversion of inactive SC members into positive and active members (Lapointe and Rivard, 2005). Lack of suitable local suppliers with the required technical skills and competence (Cragg *et al.*, 2011) need to be managed by working closely together, organizations and their suppliers may create highly competitive supply chains (Corbett *et al.*, 2012).

2.6.3 Size of targeted customer group (ST). One of the most troubling problems is "lack of preparation and size of targeted customer group"; small number of prospective customers being targeted may be a valid reason for not opting for new technology because it may lead to long recovery period (Porter, 2008).

Based on above discussions on identification of critical barriers and criteria from review of relevant literature, we proposed conceptual SWOT model as shown in Figure 1. Recipients supply chain internal environment' has been separated from "Supply chain external environment" with the help of boundary. It is obvious that technology transferor interact with the parent firm supply chain across the boundary (separating SC internal environment and external environment) through an agent.

Technology transfer needs to be carried out throughout the supply chain integrating supply chain members. All identified critical barriers' categories have been segregated into two groups: Internal barriers' group; and external barriers' group:

- External barriers may be perceived as threats or challenges, which include PB; socio-cultural barriers (external); and TB (external). Authors propose to manage these external barriers to convert them into means for developing capability towards grabbing opportunities available SC external environment.
- However, internal barriers' category includes SC barriers; EB; MB; socio-cultural barriers (internal); and TB (internal). These internal barriers may be managed effectively and efficiently to convert them into strengths for successful TT process enablement toward gaining profit and competitive advantage.
- External barriers may be seen as threats, where as internal barriers as weaknesses.

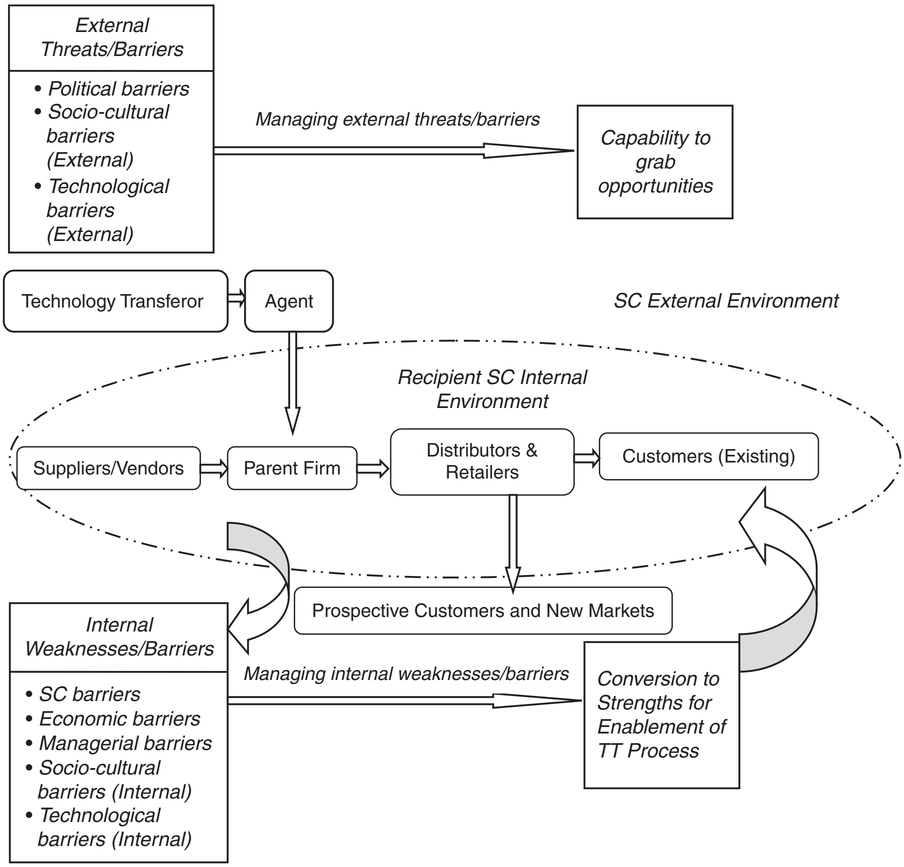

Figure 1. Conceptual SWOT model on technology transfer barriers in a supply chain

3. Methodology

Benchmarking of supply chains by analyzing TT critical barriers has been proposed to be dealt with utilizing:

- Extensive literature review – literature review has been identified an appropriate methodology to sort critical barriers to technology transfer process (Greenhalgh *et al.*, 2004) and 20 critical barriers of TT have been identified from extensive review of relevant literature.
- Experts' opinions – identified TT CBs have been validated from experts' opinions and converted in to six key criteria (from academia and industry). Experts' opinions have also been utilized to proceed toward seeking ratings for comparing criteria, CBs and supply chains; use of these ratings to develop priority matrices for evaluation of weights of criteria, CBs and supply chains has been shown in detail in Section 4.
- Analytical hierarchy process (AHP) – AHP methodology has been utilized to rank these criteria and critical barriers under each criterion. AHP framework of benchmarking of technology transfer critical barriers has been structured as

a hierarchy which includes four levels: first level comprises objective to benchmark supply chains by analyzing technology transfer critical barriers; second level suggests six identified criteria (technological, managerial, socio-cultural, political, economic and supply chain barriers) of critical barriers and comparison of these criteria to provide basis for evaluating critical barriers; third level further compares critical barriers to efficient technology transfer process successful implementation toward ranking of identified 20 critical barriers; and fourth level presents supply chains to be benchmarked. AHP frame work for benchmarking supply chains by analyzing TT critical barriers has been shown in Figure 2.

The AHP methodology compares alternatives (in pair wise mode) with respect to a criterion, and series of matrices are formed to reach to final comparison matrix to compare and rank the alternatives (critical barriers to technology transfer process in our study) for benchmarking supply chains. Although, ELECTRE and TOPSIS methods of decision making have been presented in literature to solve the multi-criteria analysis problem but a limited acceptance has been observed among the community of practitioners and scholars (Harputlugil *et al.*, 2011). However, ISM has been used in many studies for establishing of relationships among specific items/elements to define a problem or an issue by means of their dependency and driving power (Luthra *et al.*, 2011; Kumar *et al.*, 2013a, b; Mangla *et al.*, 2013). While, an AHP methodology may be used to quantify relationships and weigh the importance of different items/element; and thus enhance understanding of the system (Gorvett and Liu, 2007). DEMATEL reveals the relationships among factors and prioritizing the criteria based on the type of relationships and severity of their effects on each other criteria (Mangla *et al.*, 2014). The advantages of AHP over other multi criteria methods are its flexibility,

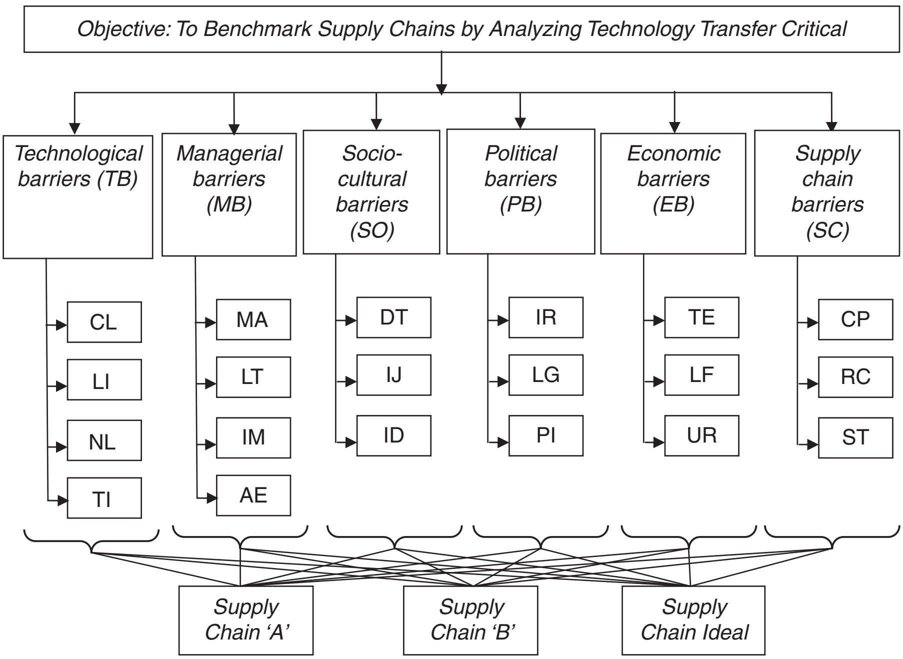

Figure 2.
AHP hierarchical model to benchmark SCs by analyzing TT critical barriers

intuitive appeal to the decision makers and its facility to check inconsistencies (Bao *et al.*, 2013; Govindan *et al.*, 2014).

AHP decision making process starts with dividing the problem into a hierarchy of issues to be considered in the work and these hierarchical orders help to simplify the illustration of the problem and bring it to a condition which is easily understandable (Harputlugil *et al.*, 2011). The final result of the approach provides the numerical priorities for each element representing the relative ability of each element to achieve the goal and AHP may be positioned to help model situations of uncertainty and risk where standardized measures do not exist (Millet and Wedley 2002). The use of AHP methodology has been reported in several decision making situations in wide-ranging fields like SCM, engineering/design, education, healthcare and management etc. (Ordoobadi, 2010).

AHP as a well-established multi criteria decision making technique has following three steps (Saaty, 1980; Saaty, 1994; Saaty, 2000; Saaty, 2008; Kumar *et al.*, 2009; Luthra *et al.*, 2013): Develop hierarchical structure (Figure 2 shows hierarchical structure to evaluate CBs of TT); Construct a set of pair wise comparison matrices using a nine-point scale; and Evaluate consistency (in terms of consistency index (CI) by using Equation (1) in which value of random consistency index (RI) may be suitably chosen from Table I depending upon comparison matrix size) in assigning ratings and value of consistency ratio need to be "equal to" or "less than" acceptable consistence ratio value, where value of acceptable consistency ratio has been suggested as: 0.05 for a 3 by 3 matrix; 0.08 for a 4 by 4 matrix; and 0.1 for all larger matrices, $n \geqslant 5$:

$$CR = CI/RI \tag{1}$$

4. Analysis of data and results

In the second session of workshop, brainstorming session between decision teams was carried out to make pair wise comparisons among the identified criteria and critical barriers based according Saaty scale (For detail see Table II).

Based on the ratings obtained by experts in brainstorming sessions during an idea engineering workshop, matrices are formed; and the priorities have been synthesized using appropriately using step wise procedure of AHP technique. AHP framework to benchmark supply chains by analyzing TT critical barriers has been structured as

Table I. Random index

Size of matrix	1	2	3	4	5	6
R.I.	0	0	0.58	0.90	1.12	1.24

Table II. Scales in pair wise comparisons

Intensity of importance	Verbal judgment of preference
1	Equally important
3	Moderately important
5	Strongly important
7	Extremely important
9	Extremely more important
2, 4, 6, 8	Intermediate values between adjacent scale values

Source: Adapted from Saaty (1980)

a hierarchy which includes four levels (discussed in Section 3). Table III shows weights given by experts to six criteria of CBs (2nd level); and priorities and their ranks. From the analytical results shown in Table III.

"PB" has been found the most important criteria of critical barriers to technology transfer followed by "Socio-cultural barriers (SO)"; "EB"; "TB"; Supply chain barriers (SC)" and "MB."

In the next level of decision making, various critical barriers under each criteria of technology transfer process have been checked for hierarchy (Table IV to Table IX). Table IV evaluates the ranking of critical barriers under criteria "TB."

"Inappropriate/incompetent technology and resource wastage in technologies imported (TI)" has been reported most critical barrier among "TB," followed by "Non availability of skilled labor (NL)"; "Lack of IT enablement, IMS and effective communication (LI)" and "Complexity (CL)" in decreasing order of importance as shown in Table IV. Further, critical barriers under criteria "MB" have been checked for hierarchy in Table V.

"MA" has been found most critical barrier in "MB," followed by "AE"; "Inefficient management of R & D activities (IM)" and "Lack of time (LT)" as identified in Table V.

Table III.
Pair wise comparison matrix of criteria

	TB	MB	SO	PB	EB	SC	Priority Matrix	Rank
TB	1	2	1	1/2	1	1	0.14999	4th
MB		1	1/3	1/5	1/2	1	0.07562	6th
SO			1	½	1	2	0.17892	2nd
PB				1	2	3	0.32891	1st
EB					1	2	0.16647	3rd
SC						1	0.10009	5th

Maximum eigen value = 6.07473
CI = 0.0149458

Table IV.
Pair wise comparison matrix of technological barriers (TB)

	CL	LI	NL	TI	Priority matrix	Rank
CL	1	1/2	1	1/4	0.12829	4th
LI		1	1/2	1/5	0.14482	3rd
NL			1	1/2	0.21053	2nd
TI				1	0.51636	1st

Maximum eigen value = 4.21161
CI = 0.0705359

Table V.
Pair wise comparison matrix of managerial barriers (MB)

	MA	LT	IM	AE	Priority matrix	Rank
MA	1	4	2	2	0.42878	1st
LT		1	1/3	1/4	0.08179	4th
IM			1	1	0.23461	3rd
AE				1	0.25482	2nd

Maximum eigen value = 4.04582
C.I. = 0.0152731

In next Table VI, critical barriers under "Socio-cultural barriers" criteria have been checked for hierarchy.

From the analytical results shown in Table VI, "Difficulty in transfer and diffusion (DT)" barrier has been reported the most critical under "Socio-cultural barriers" criteria, followed by "Government ID" and "Inefficient societal/cultural judgment (IJ)." In the next table, barriers under "PB" criteria have been checked for hierarchy.

In Table VII, "PI" barrier has been reported the most critical in "PB," followed by "Lack of collaboration between government and research institutions (LG)" and "Inactive role of change agent (IR)." In Table VIII, barriers under "EB" criteria have been hierarchically analyzed.

From the analytical hierarchical process calculations tabulated in Table VIII, "TE" barrier has been reported the most critical among barriers categorized under "EB",

	DT	IJ	ID	Priority matrix	Rank
DT	1	1	2	0.41260	1st
IJ		1	1/2	0.25992	3rd
ID			1	0.32748	2nd
Maximum eigen value = 3.21736					
C.I. = 0.108681					

Table VI. Pair wise comparison matrix of socio-cultural barriers (SO)

	IR	LG	PI	Priority matrix	Rank
IR	1	1/3	1/4	0.12196	3rd
LG		1	1/2	0.31962	2nd
PI			1	0.55842	1st
Maximum eigen value = 3.01829					
C.I. = 0.00914735					

Table VII. Pair wise comparison matrix of political barriers (PB)

	TE	LF	UR	Priority Matrix	Rank
TE	1	2	3	0.52784	1st
LF		1	3	0.33251	2nd
UR			1	0.13965	3rd
Maximum eigen value = 3.05362					
C.I. = 0.0268108					

Table VIII. Pair wise comparison matrix of economic barriers (EB)

	CP	RC	ST	Priority Matrix	Rank
CP	1	1/4	1/3	0.12196	3rd
RC		1	2	0.55842	1st
ST			1	0.31962	2nd
Maximum eigen value = 3.01829					
C.I. = 0.00914735					

Table IX. Pair wise comparison matrix of supply chain barriers (SC) followed by "Lack of funds (LF)" and "Uncertainty of recovery (UR)." Barriers under "Supply chain barriers" criteria have been checked for hierarchical importance in the next Table IX; and "Inactive role of SC members and resistance to change (RC)" barrier has been reported the most critical under "Supply chain barriers", where as "Size of targeted customer group (ST)" and "Current products meeting the needs (CP)" have been ranked next two barriers in this category.

Consistency ratio values have been found well in acceptable range for matrices shown in Table III to Table IX, which ensures decision-makers' responses reliability as per the directions given methodology mentioned in Section 3.

5. Discussions

This paper provides useful framework considering TT critical barriers making technology transfer process implementation less effective for benchmarking of supply chains (involved in technology transfer, implementation, adoption and adaption process to gain value addition and competitive advantage); and 20 critical barriers have been identified from review of relevant literature and categorized in to six criteria. AHP technique has been appropriately utilized to develop a suitable "hierarchical structural framework" for benchmarking supply chains by analyzing technology transfer critical barriers and further, to establish pair wise comparison matrices; and the outcomes of calculations carried out have been discussed as follows:

- "PB" has been rated most important criteria of critical barriers to technology transfer as compared to other criteria: "Socio-cultural barriers"; "EB"; "TB"; "Supply chain barriers" and "MB." In fact, crossing the borders of countries by the technology fairly depends upon: global political scenario; and internal political issues of the countries and interplay of actors involved.
- Further, under each criterion, critical barriers have been rated and analyzed. Among critical barriers under "PB" criteria, "PI" barrier has been identified as the most troubling. Technology transfer process may take long span of time, and sometimes few years; and political scenario in provider country and receiver country need to be expected 'politically stable; during "time frame" planned for completion of TT process implementation.
- Under "Socio-cultural barriers" criterion, "Difficulty in transfer and diffusion" has been got most critical barrier and "Inefficient societal/cultural judgment" as least hindering barrier. Social and cultural aspects and barriers need to be carefully understood, examined and tackled since prospective customers/consumers may perceive, think and then behave, toward enhanced/improved features of products/services resulting from use of new technology, according to social and cultural impacts of various socio-cultural factors on them. Elmuti and Abou-Zaid (2013) also argued that there has been a resistance to change among local citizens and societies to technology transfer especially in less developed countries.
- "Too expensive" barrier has been ranked the most important critical barrier under "EB" criterion of critical barriers to hinder technology transfer; and to deal with this barrier, cost of products/services may be kept less or rather more economical in the minds of prospective customers, which may lead to: longer recovery period; and of course, less premium; however, this situation may be managed by keeping the cost reasonably low (as compared to values offered) to attract more customers toward getting benefitting from "economy of scale."

- Further, under "TB" criterion, "Inappropriate/incompetent technology and resource wastage in technologies imported" has been reported as most important critical barrier, which may indicate toward need of managing process of technology transfer highlighting important decisions involving issues such as: identification of technology appropriateness; sourcing country and firm; and analysis of "cost and benefits", and so on. Gunawansa and Kua (2011) suggested in their research that it is important for countries to create an appropriate balance between: providing protection for IPR; and preventing the adverse impacts on the development and transfer of new technology.
- In "Supply chain barriers" criterion, "Inactive role of SC members and resistance to change" has been found as most hindering barrier to technology transfer; however, all SC members are to be managed to allow new technology absorption thoroughly throughout the SC.
- "MA" has been rated most critical barrier under "MB" criterion, since no decision may be initiated and successfully implemented without the support of top management coming forward with positive attitude.

Authors propose to use these AHP calculations resulting into overall weights of critical barriers and rankings (summarized as Table X) to benchmark supply chains. However, from Table X, it is evident that "PI", "Lack of collaboration between government and research institutions (LG)" and "Too expensive (TE)" barriers have been rated and ranked top three most critical technology transfer barriers based upon overall weights. Further, three supply chains have been considered to explain benchmarking process:

- supply chain "A" – supply chain needs to be benchmarked;
- supply chain "B" – established supply chain in the field, which has been identified successful in managing/mitigating technology transfer barriers; and
- supply chain "Ideal" – supply chain being ideal in managing mitigating barriers of technology transfer.

Calculations show that value of total of overall weights to Supply chain "A" is 5.41717 and 7.51752 for Supply chain "B", whereas this value is 8.99999 for Supply chain "Ideal." The total of overall weights to a particular supply chain may be named as "Technology Transfer Barriers Mitigation Index (TTBMI)" and found important and useful in benchmarking supply chain based on the capabilities of supply chains to manage technology transfer barriers.

6. Concluding remarks

However, with the rapid advancement of technology, product life cycle has been observed getting shortened continuously; but, in order to compete against other organizations/supply chains in fiercely competitive global markets, an organization or a supply chain has to keep developing new technology to differentiate itself from others (Lee *et al.*, 2010). This paper has been proposed to benchmark supply chains based upon their capability to mange technology transfer critical barriers mitigation efforts toward making technology transfer process implementation effective and fruitful in terms of fostering existing as well as targeted prospective customers' positive perception and satisfaction leading to competitive edge over other organizations/SCs in the segment.

Table X.
Overall priority matrix to benchmark supply chains

Criteria of TT critical (I)	Final weight of the criteria (II)	Criteria rank (III)	Critical barrier to TT (iv)	Local weight of CBs (V)	Overall weight of CBs (VI)	Overall ranking of CBs (VII)	Supply chain "A" Rating (VIII)	Supply chain "A" Overall weight to SC "A" (IX)	Supply chain "B" Rating (X)	Supply chain "B" Overall weight to SC "B" (XI)	Supply chain "Ideal" Rating (XII)	Supply chain "Ideal" Overall weight to SC "Ideal" (XIII)
TB	0.14999	4th	CL	0.12829	0.01924	17th	5	0.09620	8	0.15392	9	0.17316
			LI	0.14482	0.02172	15th	6	0.13032	7	0.15204	9	0.19548
			NL	0.21053	0.03158	13h	4	0.12632	7	0.22106	9	0.28422
			TI	0.51636	0.07745	4th	6	0.46470	9	0.69705	9	0.69705
MB	0.07562	6th	MA	0.42878	0.03242	11th	6	0.19452	8	0.25936	9	0.29178
			LT	0.08179	0.00618	20th	4	0.02472	7	0.04326	9	0.05562
			IM	0.23461	0.01775	18th	5	0.08875	6	0.10650	9	0.15975
			AE	0.25482	0.01927	16th	3	0.05781	6	0.11562	9	0.17343
SO	0.17892	2rd	DT	0.41260	0.07382	5th	5	0.36910	7	0.51674	9	0.66438
			IJ	0.25992	0.04651	9th	6	0.27906	8	0.37208	9	0.41859
			ID	0.32748	0.05859	6th	3	0.17577	7	0.41013	9	0.52731
PB	0.32891	1st	IR	0.12196	0.04011	10th	5	0.20055	7	0.28077	9	0.36099
			LG	0.31962	0.10513	2nd	6	0.63078	8	0.84104	9	0.94617
			PI	0.55842	0.18367	1st	6	1.10202	8	1.46936	9	1.65303
EB	0.16647	3rd	TE	0.52784	0.08787	3rd	5	0.43935	7	0.61509	9	0.79083
			LF	0.33251	0.05535	8th	6	0.33210	8	0.44280	9	0.49815
			UR	0.13965	0.02325	14th	5	0.11625	7	0.16375	9	0.20925
SC	0.10009	5th	CP	0.12196	0.01221	19th	7	0.08547	8	0.09768	9	0.10989
			RC	0.55842	0.05589	7th	5	0.27945	6	0.33534	9	0.50258
			ST	0.31962	0.03199	12th	7	0.22393	7	0.22393	9	0.28791
Total of overall weights to various SCs								5.41717		7.51752		8.9999

AHP technique has been suitably utilized for benchmarking supply chains by analyzing 20 technology transfer critical barriers identified from literature review and categorized in to six criteria. PB have been analyzed most significant criteria of critical barriers to technology transfer followed by Socio-cultural barriers and EB. Each criterion has been analyzed to prioritize critical barriers under it using AHP technique. "PI," "Difficulty in transfer and diffusion," "Too expensive," "Inappropriate/incompetent technology and resource wastage in technologies imported," "Inactive role of SC members and resistance to change" and "MA" have been found most hindering barriers in their respective category/criterion of technology transfer barriers.

Finally, we may conclude, on the basis of final overall weights calculated for each critical barrier, that "PI," "Lack of collaboration between government and research institutions" and "Too expensive" critical barriers have been ranked top three most important technology transfer barriers. Further, benchmarking process has been proposed to calculate value of total of overall weights to a particular supply chain named as "TTBMI" useful to present capability of supply chains to manage technology transfer barriers by a single numeric value.

6.1 Limitations and future scope of the study

Scope of the present study has been limited to propose framework to benchmark supply chains by analyzing 20 critical barriers of technology transfer grouped in to six dimensions/criteria using AHP approach based on "ratings provided by experts" (which may be biased): although, consistencies have been checked throughout the hierarchy.

However, benchmarking procedure has been dealt with using well-established methodology – AHP toward providing single numeric value index (TTBMI) indicating ability of supply chains to manage/mitigate technology transfer barriers, many issues are yet required to deal with giving directions for future research:

- case study approach may be further utilized to validate the findings resulting from application of benchmarking methodology detailed in this study;
- structural equation modeling may also be used supported by appropriately designed "questionnaire based empirical research"; and
- from "provider" developed county's view point, present benchmarking framework may be further applied to compare developing countries' ability to absorb and diffuse new technologies.

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