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An Integrated Ism and Fuzzy Micmac Approach for Modeling of the Enablers of Technology Management

KEYWORDS: Technology Management (TM), Enablers, Interpretive Structural Modeling (ISM)

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ABSTRACT *The management of technology is acquiring a distinctive character and increasingly being recognised as an activity that complements other managerial functions in providing the necessary inputs for the decision-making process. The factors that are helpful in the implementation of Technology Management (TM) are known as enablers. Present study aims to develop the relationships among the identified TM enablers. The relationship presented in the paper would help in understanding the mutual influence of enablers and also to identify those enablers which support other enablers (driving enablers) and those enablers which are most influenced by other enablers (dependent/driven enablers). An integrated Interpretive Structure Modeling (ISM) and Fuzzy MICMAC methodology is used to establish the mutual relationship among the enablers. TM enablers have been classified as either driving or driven enablers based on their driving and dependence power.*

1. Introduction

Technology management is a process, which includes planning, directing, control and coordination of the development and implementation of technological capabilities to shape and accomplish the strategic and operational objectives of an organisation (Task Force on Management of Technology, 1987). Technology management includes: (1) planning for the development of technology capabilities; (2) identifying key technology and its related fields for development; (3) determining whether 'to buy' or 'to make', i.e., whether import or self-development should be pursued; and (4) establishing institutional mechanisms for directing and coordinating the development of technology capabilities, and the design of policy measures for controls (Wang, 1993). Technology management is the capacity of a firm, a group, or a society, to master the management of the factors that leads to technical change with the purpose of improving its economic, social and cultural environment and increasing its wealth quotient. The overall process of technology management can be divided into the following eight phases, i.e., (i) Forecasting and assessment, (ii) planning and strategy, (iii) acquisition and development, (iv) transfer, (v) adoption and adaptation, (vi) diffusion and substitution, (vii) utilization, and (viii) phasing–out (Singh & Sushil, 2001).

1.1 Problem Statement

There has been growing interest among firms in the profitable exploitation of their technological assets through implementation of technology management processes. Most developing countries are actively seeking various ways to enhance their economic development and improve the quality of life of their people, and often see technology management as a mechanism to achieve these goals. However, these nations have not yet succeeded in implementing technology management processes because they probably are not aware of the associated enablers and also they have not yet understood the relationship among these enablers.

This paper addresses a problem which focuses on the identification of enablers pertaining to the implementation of technology management processes in order to establish a relationship in terms of dependency and driving power of the identified enablers.

1.2 Methodology

A large number of papers available in the literature on technology management concepts for the identification of key issues and strategic risks involved in it were reviewed. Seven key enablers (Table 1) of TM were identified based on the literature review. The enablers listed in Table 1 have been explained in the following sub-section. ISM approach, followed by identification of enablers, was used to develop an ISM model to depict the relationships among these enablers. Further, to strengthen the relationships among enablers of ISM model, Fuzzy MICMAC was employed. Results of ISM model was validated based on the feedback received from the subject experts by serving them a questionnaire.

Table .1 Description of Enablers and their references.

Enablers Number	Enablers Description	References
1	Technology recipient characteristic (Absorptive Capacity, Recipient Collaborativeness)	Cohen & Levinthal (1990)
2	Technology supplier characteristics (motivation, partner transparency Disseminative capacity, control, prior experience, transferor's commitment, articulated objective Source trnsfer capacity)	Gupta & Govindarajan (2000)
3	Relationship characteristic (Relationship Quality and Mutual trust)	Rose et al., (2009)
4	Large and stable demand	Stern (2007)
5	Governmental policies and R&D Investment	Nguyen et al., (2010)
6	Technological innovation	Utterback (1974)
7	Cross cultural training	Black & Mendenhall (1990)

2.1 Technology Recipient Characteristic

Technology recipient characteristic have two critical dimensions, i.e., absorptive capacity and recipient collaborativeness. Both characteristics have a positive impact on the degree of technology transfer (Rose, et al., 2009). Technology transfer involves the process of transmission and absorption of knowledge (Davenport & Prusuak, 2000), the recipient firm's ability to absorb the knowledge transfer depends on the degree of absorptive capacity of the firm. A low degree of the technology recipient's absorptive characteristic impedes both intra-firm and inter-firm knowledge transfer (Cohen & Levinthal, 1990; Lane et al., 2001; Gupta & Govindarajan, 2000, Minbaeva, 2007). Recent research by Escribano et al. (2009) suggested that the capacity for absorption is, in fact, a capacity of the local company that plays a crucial and important role in the technology transfer process.

Technology absorption is a costly learning activity that a firm can employ to integrate and commercialise knowledge and technology that is new to the firm (Goldberg et al., 2008). Examples of absorption include adopting new products and manufacturing processes developed elsewhere, upgrading old products and process, improving organisational efficiency, achieving quality certification, etc., (Hasan et al., 2009).

Technology absorptive capacity is important in establishing technology transfer activities in firms. In a study by Kneller (2002), it was suggested that technology absorptive capacity would contribute to a firm's ability to adopt a particular technology. Madanmohan et al. (2004) suggested that the extent of a firm's technology absorptive capacity will determine its level of participation in technology transfer process and the type of technology that the firm can operate efficiently. Meanwhile, studies (Aadam & Lamont, 2003) had also discussed transformative capacity which could enhance technology absorptive capacity. Griffith, et al. (2004) had defined absorptive capacity at the firm level as its capacity to assess the value of external knowledge and technology, and to make necessary and organisational changes to absorb and apply these in its productive activities.

Research conducted by Lin et al., (2002) brought out that technology transfer performance of an organisation are greatly impacted by the technology absorptive capacity which involves change in the organisational culture, interaction mechanisms and R&D resources investment. Several studies have pointed out the importance of absorptive capacity in improving technology transfer performance (Santangelo, 2000). In addition, several studies has proposed that to understand the source of an organiation's absorptive capacity, one should focus on the structure of communication between the external environment and the organisation, as well as among the sub-units of the organisation (Grant, 1996).

Strong technology absorption capabilities (particularly in recipient firms) have been found to greatly influence the success of any technology transfer. For instance, the rapid technology capability-building in several industries in Japan, Korea, and Taiwan is attributed partly to their extremely strong technological absorption process. The relative spend on absorption/acquisition is much higher in these countries. This may not be the case of India (Sushil, 2001).

Recipient collaborativeness is defined as "the recipient firm's willingness to establish a mutually beneficial and collaborative relationship: which requires the firm's honest intention to create common benefits for both the supplier and recipient" (Child & Faulkner, 1998). Recipient collaborativeness is mostly involved in inter-firm knowledge transfer between partners in collaborative relationships such as strategic alliance and joint ventures. Strategic alliances provide an ideal platform for organisational learning, especially through IJVs, where partner's firms can acquire, learn, create new knowledge, and transfer knowledge between them (Inkpen, 2000). Learning in the collaborative relationship greatly depends on the partners' learning objective relationship greatly depends on the competitiveness (Child & Faulkner, 2006).

2.2 Technology Supplier Characteristic
Researchers such as Rose, et al., (2009) have identified numerous supplier characteristics in their study. The characteristics listed include: motivation (Gupta & Govindarajan, 2000), partner assistance (Lyles, et al., 1999), partner transparency (Hamel, 1991), disseminative capacity (Minbaeva & Michaiova, 2004), control (Lyles et al., 2003), prior experience (Subramanian & Venkataman, 2001), transferor's commitment (Tsang, et al., 2004), articulated objective or goal clarity (Inkpen, 2000) and source transfer capacity (Martin & Solomon, 2003) to have significant influence on knowledge transfer.

The technology-suppliers, as a source of knowledge, must be knowledgeable enough to form a knowledge gap between the transferor and the transferee; where they are perceived as reliable or valuable source of knowledge and must also be willing to support and cooperate with the local partner in transferring technological knowledge (Simonin, 1999a).

Technology supplier characteristic have two critical behavioural characteristics, namely, Partner protectiveness and Transfer capacity. Partner protectiveness is significantly related to the degree of transparency. Transparency is defined as the "the degree of openness of one partner (technology-supplier) and his willingness to transfer knowledge to the other partner (technology recipient)" (Hamel, 1991). Transparency provides an opportunity to learn more about the practices of world class organisations they ally with (Doz & Hamel, 1998).

The efficiency in transmitting technology or knowledge by the supplier is important in both inter and intra-firm knowledge to the subsidiaries efficiently and can effectively serve several objectives, such as to facilitate their expansion in foreign countries, to maintain the firm's competitiveness and to safeguard their competencies from the competitors. (Martin & Solomon, 2003)

2.3 Governmental Policies and R&D Investment
The government has identified that it may need to help businesses participate in globing markets - in particular, manufacturing small medium enterprises which continue to face obstacles in accessing global value chains in high growth new emerging markets (DIUS, 2008). Many governments around the world are looking for increased contributions to national R&D efforts from the private sector firms and multinationals (Dodgson, 2000). Tax relief for R&D expenditure encourages companies to venture more into R&D. Awarding of financial support to inventors and immigrant entrepreneurs, bestowing gifts of machinery, allowing rebates and exemptions on duties for import of industrial equipment aid innovation by encouraging companies to venture more into R&D. Decrease in depreciation rates will help to increase investment in high technology plant and machinery (Knight, 1996). According to Knight (1996), taxation of new products, processes and services, which are undergoing the transition to full commercialisation, acts as a barrier. Inappropriate government tax is seen as a barrier as it restrains innovation (Pihkala et al., 2002).

Authors Alinaitwe et al. (2007) undertook a survey on building contractors in Uganda, a developing country. It emerged that the level of R&D at the national level is viewed as the second most important enabler to innovation - with a mean rating of 3.91.

In order to enhance industrial development in Tanzania, the government has established supportive industrial R&D organisations such as the Tanzanian Industrial Research and Development Organisation (TIRDO); the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC); The Tanzania Education and Micro Business Opportunity (TEMDO); Tanzania Bureau of Standards (TBS); Small Industries Development Organisation (SIDO); Board of External Trade (BET); Tanzania Industrial Studies and Consulting Organisation (TISCO); COSTECH (advises the Ministry of Science, Technology and Higher Education and coordinates policy; it also promotes research activities throughout the country (Szogs, 2010).

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Malik's (2002) developed technology transfer broadcast model. In his study, he concentrated on intra-firm technology transfer. The model considers one of the most important factors – the Government's role.

Government could play a positive role in the cultivation of technological capabilities of local firms through various policy instruments and programmes (Madu, 1989). These include: raising R&D expenditure; upgrading the country's science and technology infrastructure education, training, equipment, facilities, reforming laws, bureaucratic rules, procedures, and organisation cultures that interfere with the transfer process; improving public institutions; fostering linkages among technology institutions in developing and developed countries; setting up incentive schemes; and providing information and expertise to help 'bundle' the technology package.

Sushil (2001) discussed issues involved in planning and implementing technology transfer projects. R&D is an important input for building technological capability. By providing support in absorbing new technology within a given framework, R&D serves an important purpose in the manufacture of automobile components since customers are constantly demanding their preferred choice. Organisations that have an impressive in house R&D records are more comfortable and successful in enhancing their abilities to ensure that the technology absorption process is smooth and fruitful.

2.4 Large and Stable Demand

The private sector, owner of most climate change technologies and responsible for most Technology transfer, is attracted by the prospect of a large and stable demand. The success of China, India and Brazil in attracting and deploying foreign technologies and growing domestic renewable energy industries seems to confirm this point (Pueyo et al., 2011). A large market allows technology businesses to build a significant production scale and achieve lower production costs as a result of economies of scale and technological learning curves (Stern, 2007). It also provides scope to develop a wide portfolio of low-carbon technologies. Countries with a small demand would instead be expected to have a narrower portfolio, focused in the technologies where they have significant competitive advantages.

A significant local demand is necessary to attract foreign technology leaders. Foreign investors are usually attracted by large markets and are willing to share knowledge assets in exchange for the large future profits that these markets can offer.

2.5 Technological Innovation

Innovation, which according to Firth and Mellor (1999) means the application of new knowledge to industry including new products, new process, social and organizational change, is therefore desirable. Technological innovation plays a central role in improving productivity and developing new products and services, and in providing comparative and absolute advantages (Dodgson, 2000). According to Freeman & Soete (1997), intangible investment in new knowledge and its dissemination are the more critical elements rather than tangible investments in bricks and machines. It is widely acknowledged that technological innovation in manufacturing firms is one of the main reasons for industrial competitiveness and national development (Freeman & Soete, 1997). Innovation is essentially about change and is often disruptive, risky and costly (Boyer & McDermott, 1999).

Learning and innovation are key determinants of growth and competitiveness of nations, regions, clusters and firms both in developed as well as in developing countries, in general, and least developed countries (LDCs), in particular (Lundvall et al., 2009; UNCTAD, 2007). Universities in developing countries can play a role in building capabilities in the innovation system of developing and LDCs under certain conditions (Brundenius et al., 2009). Innovation is as important for low income countries as it is for developed countries (Chaminade et al., 2009). The low incomes that characterise developing countries are a result of their low average productivity - reflecting "their limited capacity to develop new or to adopt and improve upon existing technologies" (Altenburg, 2008).

Advancement in technology can only be achieved through innovation and research and development (Madu, 1989). In the contemporary context the innovation in industry involves research and development. It brings technological change which has a far reaching impact on economic growth, industrial productivity, international competition and trade.

According to Lundvall (1992), a national system of innovation is constituted by institutions and economic structures, affecting the rate and the direction of technological change in the society. It must, for example, include means to assess how new technology affects productivity and economic growth.

In order to bring in appropriate technological innovation, innovation actors would need to cooperate very closely with each other, based on a strong level of trust, with governments needing to ignite and promote the trust and the interaction between the different constituents of national system of innovation (APCTT, 2009).

Innovation studies aim to understand how innovation can support economic growth, development and catching up also in LDCs (Lundvall, et al., 2009; Mytelka, 1993; Ernst & Lundvall, 1997; Arocena & Sutz, 1999; Johnson & Segura-Bonilla, 2001).

2.6 Cross-Cultural Training

Black & Mendenhall (1990) present a case for cross-cultural training. They argue that cross-cultural training - which is defined as having each party to the transaction host their counterpart for training - is more effective than ordinary training, because it increases the effectiveness of individuals in their new roles. Cross-cultural training becomes more important in the context of LDCs due to lags in procuring and developing new technology. By availing of cross-cultural training in developed countries, firms in LDCs get an opportunity to view and become familiar with new technology. Cross-cultural training is, therefore, an important method of technology transfer for LDCs' firms.

Cross-cultural training increases the capacity of the firm to absorb new technology by allowing employees to come in contact with new technologies and to view, first hand, other ways of producing the product. Cross-cultural training should then be related to the rate of new technology acquisition because: (1) it allows learning by observation in a different context, and (2) it increases the ability of the firm to absorb new technology. Thus, recipient firms with higher levels of cross- cultural training should be more apt to review and adopt new technology (Castro & Schuze, 1995). Cross-cultural training help increase the absorptive capacity of the firm (Cohen & Levinthal, 1990) and hence, the firm's ability to compete on a technological basis. Richard Li-Hu, (2010), mentioned that opportunities and Challenges in International Technology Transfer through tacit Knowledge Transfer is achievable if cross-culture team building exists.

2.7 Relationship Characteristics

Based on literature review, relationship quality and mutual trust are expected to have a positive impact on degree of technology transfer (Rose et al., 2009).

In order to facilitate intra and inter-firm technology transfer, both the technology supplier and technology recipient are expected not only to establish a close relationship between them, but also develop relationship quality. Relationship quality creates higher relationship openness which directly affects the willingness of alliance partners to share information and communicate openly (Inkpen, 2000; Lin, 2005).

Inter-partner mutual trust is critical in the collaborative relationship, since it:

- Develops a sense of openness and shared understanding between partners (Dyer & Nobeoka, 2000).
- Facilitates greater accessibility to the alliance knowledge and knowledge acquisition (Inkpen, 2000).
- Creates opportunities for a mutual inter-organisational learning: when partners become more open and committed in sharing their knowledge and competencies (Inkpen & Dinur,1998; Inkpen & Beamish, 1997)
- Reduce the partners' protectiveness of their knowledge and promotes free exchange of information between partners (Inkpen, 2000)
- Create higher propensity of inter-partner learning as knowledge is more accessible due to free exchange of information (Doz & Hamel, 1998; Inkpen, 2000)
- Reduce the fear of opportunistic behaviours of the learning partner and promotes greater transparency between the exchange processes (Gulati,1995)
- Promotes knowledge acquisition and inter-organisation learning (Glaister et al., 2003)
- Fosters norms of reciprocity (Nahapiet & Ghoshal, 1998).

The partner's openness or transparency, which determines the willingness to exchange, share and transfer knowledge between alliance partners, is primarily hindered by a mutual suspicion of opportunistic behaviours. (Kale et al., 2000). High degree of mutual trust indicates that the partners in a collaborative relationship accept each other as allies not as competitors, signifies the partners' commitment not to take advantage on the other partner's weaknesses and or vulnerabilities (Steensma & Lyles, 2000), and contributes to information learning and sharing: when partners are less suspicious of the other partner's opportunistic behaviours (Child & Faulkner, 1998). Trust allows potential access to the alliance's valuable resources and a willingness to solve problems (Uzzi, 1997). Trust is also crucial in alliances and joint ventures as no contracts/agreements can cover all the variations and condition that can occur (Dhanaraj et al., 2004).

A trustworthy partner builds trust and hence increases effectiveness of the alliance as it reduces cost of governance or safeguard mechanisms for deterring opportunistic behaviours of partners and opens possibilities for newer transactions that may not be possible with governance (Barney et al., 1994). Trustworthiness of firms are increased with social aspects of the relationship, such as the social network in which firms are positioned, cultural and organisational similarity, reputation, previous ties and propensity to trust (primarily based on past experiences and an environment of mutual trust) (Bierly & Gallagher, 2007).

The partner–specific learning involves the process of learning from and about an individual partner. This is very critical when there is an exchange of tacit, specialised and complex knowledge (Parise & Henderson, 2001). Transparency brings an opportunity to learn more about the practices of world-class organisations that they ally with (Doz & Hamel, 1998). Haque, et al. (2004) reported that supportive and open behaviour with honesty can create successful alliances. Kauser & Shaw (2004) have found an empirically higher level of trust in successful alliances than in their less successful counterparts. The trust-based relationship, therefore, aids in the success of alliances.

Trust is one of the aspects of the knowledge friendly cultures that fosters the relationship between individuals and groups, thereby facilitating a more proactive and open knowledge sharing (Alawi et al., 2007).

3 ISM and Fuzzy Micmac METHODOLOGY
ISM is a well established methodology for identifying relationships among specific items which define a problem or an issue (Warfield., 2005). The opinions from a group of experts are used in developing the relationship matrix, which is later used in the development of the ISM model.

3.1 Structural Self-Interaction Matrix (SSIM)
Structural self interaction matrix is developed by the use of experts' opinions. Pair-wise comparison is done among the factors to know the direction of their relationship. Based on the opinion of experts Table 2 is developed. Four symbols are used to denote the direction of relationship between the criterion (i and j):

V: criterion i will help to achieve criterion j;

A: criterion i will be achieved by criterion j;

X: criterion i and j will help to achieve each other

O: criterion i and j are unrelated.

Reachability Matrix
The SSIM has been converted into a binary matrix, called the reachability matrix by substituting X, A, V and O by 1 and 0. Then, its transitivity is checked. If factor i leads to factor j and factor j leads to factor k, then factor i would lead to factor k. By embedding transitivity, a modified reachability matrix is obtained. The situation may be shown as follows:

- if the entry in the SSIM is V, then (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0
- if the entry in the SSIM is A, then (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1
- if the entry in the SSIM is X, then (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 1
- if the entry in the SSIM is O, then (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 0.

Following these rules, an initial reachability matrix for the factors is prepared. This matrix is further iterated into a final reachability matrix and is shown in Table 3. The final reachability matrix is obtained by incorporating the transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if an enabler A is related to B and B is related to C, then A is necessarily related to C. Table 4 shows the final reachability matrix with the transitivity.

3.2 Level Partitioning
Components of a structure can be aggregated into levels. A level is itself a set, composed of those factors that lie in the same relative position in a structure. This designation into levels is of great assistance when discussing the relationships in a hierarchy, using the hierarchy itself as a visual aid to the discussion. From the final reachability matrix, the reachability set and antecedent set for each factor has been determined. The reachability set consisted of the factor itself and other factors, which it may help to achieve, whereas the antecedent set consists of the factor itself and the other factors, which may help in achieving it. Subsequently, the intersection of these sets is derived for all the factors. The factor for which the reachability and intersection sets were the same is the top-level factor in the ISM hierarchy. The top-level factor in the hierarchy would not help achieve any other factor above its own level. Once the top-level factor is identified, it is separated from the other factors. Then, with the same process, we find the next level of a factor. This process continues till the levels of each factor are identified. These identified levels help in building the digraph and hence the final model. In the present case, the factors along with their reachability set, antecedent set, intersection set and levels are shown in Tables 5–8. The process was completed in three iterations.

In table 4, the driving power and dependence of each factor are also shown. Driving power for each factor is the total number of factors (including itself), which it may help achieve.

On the other hand, dependence is the total number of factors (including itself), which may help in achieving it. An ISM model is thus generated by putting the factors according to their levels in a directed graph shown in Figure 1. The factors categorized at level-I are put at the lowest hierarchy in the ISM model and the higher level factors are placed at higher hierarchy the model. The factors at the lowest level in the ISM are the factors with highest driving powers and the factors which are at the upper level in the ISM model are the factors with low driving power.

From the ISM model, it is observed that the factor technology innovation is highly dependent factors and it does not drive any other factor in the system, instead it is driven by other factors. These factors are totally dependent on other factors. On the other hand, the factors like government policy, technology supplier characteristic, cross-culture training, relationship characteristics are at the lower levels of hierarchy which means that they are highly driving factors, they do not depend on other factors and the drive all other factors in the system. The factors which are at the intermediate hierarchy level are the factors which are both dependent and driving in nature.

3.3 Fuzzy-MICMAC Analysis

Examinations of direct relationships may reveal that indicators having strong direct impact can be suppressing hidden indicators, which at times may substantially influence the system under consideration (Abbasi, 2000). Such indirect interrelationship between indicators may have an impact on the system through influence chains and reaction loops, or feedback. The number of such chains and loops could be so large that it may be difficult to interpret them without the help of computers. To analyze these inter-relationships and to study their role and behavior, MICMAC method was introduced by Godet (Godet, 1986). MICMAC (a French term: Matrice d'Impacts Croisés Multiplication Appliquée á un Classement, i.e. cross-impact matrix -- multiplication applied to classification) is used for the analysis of the indirect and hidden relationships among the elements of the structure obtained using ISM technique (Kanungo, 1999).

3.4 Direct relationship matrix

The direct and indirect relationships among the enablers are carried out by ISM and Fuzzy MICMAC. A direct reachability matrix is obtained by examining the direct relationship among the criterion in the ISM as given in Table-2. The transitivity is ignored and the diagonal entries are converted to zero. The direct reachability matrix so derived, is shown in Table-9.

3.5 Development of Fuzzy Direct Relationship Matrix (FDRM)

The analysis can be further improved by considering the possibility of reachability instead of the mere consideration of reachability used so far. Conventional MICMAC considers only binary type of relationships, so fuzzy set theory has been used to increase the former's sensitivity. In fuzzy MICMAC analysis, an additional input of possibility of interaction between the elements is introduced. The possibility of interaction can be defined by qualitative consideration on 0–1 scale and is given in Table 10 (Lal & Haleem, 2009).The possibility of numerical value of the reachability is superimposed on the Direct Relationship Matrix (DRM) to obtain a Fuzzy Direct Relationship Matrix (FDRM) as shown in Table 11.

3.6 Stabilization of Fuzzy Direct Relationship Matrix

For the stabilization of fuzzy-direct relationship matrix, the matrix is multiplied with itself until the hierarchies of driving power and dependence are stabilized i.e. they start repeating. Fuzzy matrix multiplication is basically a generalization of Boolean Matrix Multiplication (Khurana, 2010; Sheng, 1995). According to Fuzzy Set Theory (FST) (ISO 14040, 2006), when two fuzzy matrices are multiplied, the product matrix is also a fuzzy matrix. Multiplication follows the given rule (Kandasamy, 2007): Product of the fuzzy set A and fuzzy set B is fuzzy set C.

AB =Max {min (aij, bij)}

Where, A= [aij] and B=[bij] are two fuzzy matrices

The driving power of the factors in Fuzzy-MICMAC is derived by summing the entries of possibilities of interactions in the rows. The dependence of factors is determined by summing the entries of possibilities of interactions in the columns. The values of the driving power of the factors decide the hierarchy of the technology management enablers. The stabilized matrix in Fuzzy-MICMAC for technology management enablers is achieved at this stage. A stabilized matrix is shown in Table 12.

Table 2: Structural Self-Interaction Matrix

S.NO.	FACTORS	7	6	5	4	3	2
1	Government Policy and Investment	O	V	V	X	V	O
2	Technology Supplier Characteristics	O	V	V	X	X	
3	Cross Culture Training	O	V	V	V		
4	Relationship Characteristics	O	V	V			
5	Technology Recipient Characteristics	O	V				
6	Technology Innovation	A					
7	Large And Stable Demand						

Table 3: Initial Reachability Matrix

Barriers	1	2	3	4	5	6	7
1	1	0	1	1	1	1	0
2	0	1	1	1	1	1	0
3	0	1	1	1	1	1	0
4	1	1	0	1	1	1	0
5	0	0	0	0	1	1	0
6	0	0	0	0	0	1	0
7	0	0	0	0	0	1	1

Table 4: Final Reachability Matrix

Factors	1	2	3	4	5	6	7	Driving power
1	1	1*	1	1	1	1	0	6
2	1*	1	1	1	1	1	0	6
3	1*	1	1	1	1	1	0	6
4	1	1	1*	1	1	1	0	6
5	0	0	0	0	1	1	0	2
6	0	0	0	0	0	1	0	1
7	0	0	0	0	0	1	1	2
Dependence power	4	4	4	4	5	7	1	

Table 5: Levels of critical factors, iteration 1

Factors	Reachability Set	Antecedent set	Intersection	Level
1	1,2,3,4,5,6	1,2,3,4	1,2,3,4	
2	1,2,3,4,5,6	1,2,3,4	1,2,3,4	
3	1,2,3,4,5,6	1,2,3,4	1,2,3,4	
4	1,2,3,4,5,6	1,2,3,4	1,2,3,4	
5	5,6	1,2,3,4,5	5	
6	6	1,2,3,4,5,6,7	6	Level I
7	6,7	7	7	

Table 6: levels of critical factors, iteration 2

Factors	Reachability Set	Antecedent set	Intersection	Level
1	1,2,3,4,5	1,2,3,4	1,2,3,4	
2	1,2,3,4,5	1,2,3,4	1,2,3,4	
3	1,2,3,4,5	1,2,3,4	1,2,3,4	
4	1,2,3,4,5	1,2,3,4	1,2,3,4	
5	5	12345	5	Level II
7	7	7	7	Level II

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Table 7: levels of critical factors, iteration 3

Factors	Reachability Set	Antecedent set	Intersection	Level
1	1,2,3,4	1,2,3,4	1,2,3,4	Level III
2	1,2,3,4	1,2,3,4	1,2,3,4	Level III
3	1,2,3,4	1,2,3,4	1,2,3,4	Level III
4	1,2,3,4	1,2,3,4	1,2,3,4	Level III

Table 8: levels of factors

Factors	Reachability Set	Antecedent set	Intersection	Level
1	1,2,3,4,	1,2,3,4	1,2,3,4	Level III
2	1,2,3,4,	1,2,3,4	1,2,3,4	Level III
3	1,2,3,4,	1,2,3,4	1,2,3,	Level III
4	1,2,3,4,	1,2,3,4	1,2,3,4	Level III
5	5	1,2,3,4,5	5	Level II
6	6	1,2,3,4,5,6,7	6	Level I
7	7	7	7	Level II

Table 9: Binary direct relationship matrix

Factors	1	2	3	4	5	6	7
1	0	0	1	1	1	1	0
2	0	0	1	1	1	1	0
3	0	1	0	1	1	1	0
4	1	1	0	0	1	1	0
5	0	0	0	0	0	1	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	1	0

Table 10: Possibility of numerical value of the Reachability

Possibility of Reach-ability	No	Negligible	Low	Medium	High	Very High	Full
Negligible	0	0.1	0.3	0.5	0.7	0.9	1

Table11: Fuzzy direct relationship matrix

Factors	1	2	3	4	5	6	7
1	0	0	.1	.3	.7	.9	0
2	0	0	.7	.9	.5	.7	0
3	0	.1	0	1	.3	1	0
4	.1	1	0	0	1	1	0
5	0	0	0	0	0	1	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	1	0

Table 12: Fuzzy MICMAC stabilized matrix

factors	1	2	3	4	5	6	7	D.P.
1	.1	.3	.3	.3	.3	.3	.3	1.9
2	.1	.7	.7	.9	.7	.7	.9	4.7
3	.1	.7	.7	.9	.7	.7	.9	4.7
4	.1	.7	.7	.7	.9	.9	.7	4.9
5	0	.0	.0	.0	0	0	0	0.0
6	0	.0	.0	.0	0	0	0	0.0
7	0	.0	.0	.0	0	0	0	0.0
Dependence	.4	2.6	2.4	2.8	2.6	2.6	2.6	

Figure.1 ISM Model

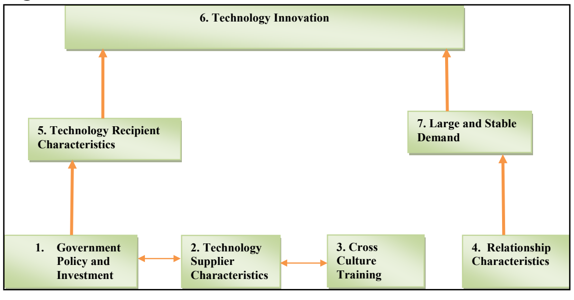
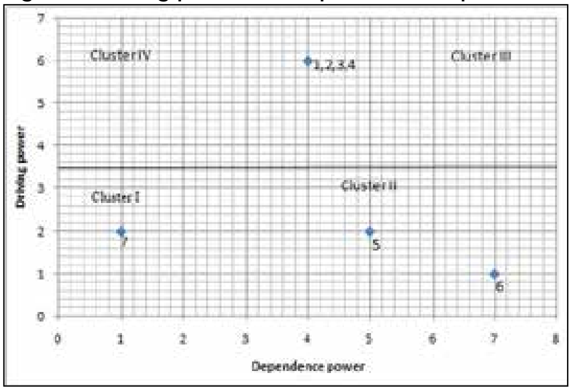


Figure 2: Driving power and Dependence Graph



3.3 Classification of Enablers

All enablers have been classified, based on their driving power and dependence power, into four categories as: autonomous enablers, dependent enablers, linkage enablers, and independent enablers. These classifications of enablers are similar to the ones used by Mandal & Deshmukh (1994). The driving power and dependence power diagram for enablers is shown in Figure 2. It is observed that enablers 1, 2, 3, 4 has a driving power of 6 and a dependence power of 4 (see Table 4) and, therefore, these are positioned at a place which corresponds to a driving power of 6 and a dependence power of 4, as shown in Figure 1. The objective behind the classification of enablers is to analyse the driving power and dependence power of the enablers. In this classification of enablers, the first cluster is of autonomous enablers that have a weak driving power and weak dependence power. The autonomous enablers are relatively disconnected from the system. In the present case, there is one autonomous enabler and that is 7. The second cluster consists of dependent enablers that have a weak driving power and strong dependence power. In the present case, enablers 5 and 6 are in the category of dependent enablers. The third cluster consists of linkage enablers that have strong driving and dependence power. Any action on these enablers will have an effect on the other enablers and also a feedback effect on themselves. In this case, there are four linkage enablers. The fourth cluster includes independent enablers that have a strong driving power and weak dependence power. In this case, there are no independent enablers.

4. Validation of The ISM Results

Based on the results of ISM model, a questionnaire consisting of a set of specific questions pertaining to the driving and dependence/ driven power of the enablers was prepared and served to 93 subject experts. They were requested to give their feedback for each question of the questionnaire. 11 out of 93 experts did not respond and the responses from 8 experts were not included in the study as their responses were incomplete. On the basis of the average responses, it was found that responses from 86.48 % (64 subject experts) were in agreement with those of the results of ISM model. This verifies and validates results of the integrated ISM and Fuzzy MICMAC model proposed in the present paper.

5. Conclusion

The levels of enablers are important in understanding of successful Technology Management implementation. Government policy investment, technology supplier characteristics, cross-culture training, relationship characteristics are the most important enablers due to their high driving power and low dependence among all the identified TM enablers. These enablers are positioned at the lowest level in the hierarchy of the ISM model. The enabler technology innovation is at the highest level in the ISM model due to its high dependence power and low driving power.

The model presented in this paper may enable management involved in technology management and decisions-makers to identify and classify the enablers that have either strong dependence or strong driving power or both strong dependence and driving power that ultimately enhances the process of technology management.

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