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Abstract

Purpose: Technology and knowledge have become the buzzwords of the new millennium. Technological changes and demanding customers are creating a more knowledge intensive, turbulent, complex, and uncertain environment. Organizations, which are able to continually build new strategic assets faster and cheaper than those of their competitors, create long-term competitive advantages. Thus, growth of companies is directly associated with innovativeness and technological development, especially for small organizations which are more vulnerable to dynamic changes in market place. Organizations need a strategic framework which can help them to achieve the goal of technology development and competitiveness. The objective of this study is to develop such strategic framework for small organizations for their technology development and hence survival in marketplace.

Methodology: Options field methodology (OFM), options profile methodology (OPM), analytical hierarchal methodology (AHP) and fuzzy set theory (FST) are utilized to generate various options and profiles to propose a conceptual framework for technology development.

Findings: The results from the study showed that "mixed approach", "strategic simulation approach", and the "regulatory environment approach", in this order, emerged as the top three important options for strategic technological development of small manufacturing enterprises.

Originality/Value: This result can provide an original and more accurate implementation pathway towards technological innovative development in emerging economies. The proposed framework can provide valuable guidelines and recommendations to practicing managers and analysts for policy development to promote innovative and technological developments.

Keywords – manufacturing strategy; technology development; SMEs; innovation.

1. Introduction

The industrial scenario in the country has undergone a sea-change consequent to globalization and liberalization of economy that began in early nineties. After liberalization was initiated, leading international players targeted India as a key investment opportunity in all areas (Sethi and Sushil, 2000). Fierce competition has come in both from local and global markets. This competition is marked by rapid technological developments and unprecedented obsolescence rates. Today, the biggest challenge before Indian industry is to generate the knowledge base for producing technologies and core competencies to remain competitive globally. This requires extensive research and development efforts for indigenous technology development. In the pre-liberalized Indian economy, organizations had not bothered to invest in research and development. Even after opening up of the economy, they relied and are still relying heavily on external acquisition of technology. The Indian industry, especially small enterprises has to move away from its complacent approach towards technology upgradation initiatives and start managing innovation in research and development activities to develop cutting edge technologies and products.

The survival and success of small enterprises largely depend on their ability to innovate, create and discover new ways of doing business (Dubey et al., 2015; Gupta and Barua, 2018b; Martins and Terblanche, 2003; Popa et al., 2017; Yang, 2007). Rapidly changing technologies and customer requirements have created a turbulent work environment (Baba et al., 2006; Singh *et al.*, 2008; Muhammad *et al.*, 2010). Organization's success depends on its ability to provide new products using cutting-edge technologies at a faster pace than their competitors. Organizations need to excel in all aspects of their businesses without any compromise in innovativeness and customer responsiveness. Therefore, organizations need to focus on developing competencies and resources so as to be able to face stiff competition. Those organizations that are able to strategically develop their technological base and create innovative products and technologies at a cheaper and faster rate than their competitors are better placed in a competitive environment (Ajitabh and Momaya, 2004; Hungund and Mani, 2019).

The framework identifies the best approaches to boost technological development of small manufacturing enterprises. The approaches considered in this work are:

- Strategic Stimulation based Approach (S_{ba}): This approach focuses on building a conducive and supportive internal environment to encourage and motivate employees for technology capability building of the organization.
- Technology-based approach (T_{ba}): This approach focuses on building an adequate research infrastructure for product and process innovations.

- Regulatory Environment based approach (R_{ba}): This approach emphasizes on providing a supportive policy framework for technology development programs of small-scale sector.
- Nucleus-based approach (N_{ba}): This approach focuses on obtaining operational support and capabilities through alliances and interactive learning networks.
- Mixed approach (M_a): This approach uses a mix of features of the above profiles. It strategically utilizes the key elements of different profiles to implement the required options to meet an objective.

In this work, the difficulties faced by small manufacturing enterprises when attempting to initiate technological developments to aid in developing an original structured framework for the technological development of these organizations is identified. The framework unveils the best approaches to boost technological development of small manufacturing enterprises. Understanding technology development of companies located in emerging economies remains as an important gap in the state of the art literature on small manufacturing firms (Guimarães et al., 2016). Overall, most of the theory in operations and production management is generated in mature economies, and it is necessary to understand the peculiarities of emerging economies (Mexas et al., 2012).

The rest of the paper is structured as follows. Section 2, the theoretical development, presents literature regarding the identified factors of innovation and technological development. The methodology adopted and utilized in the study is discussed in section 3. In section 4, learning issues about each factor is presented and, the modeling results are presented in section 5. Section 6 discusses the various approaches for technology development and section 7 presents a conceptual framework developed for technology development. Finally, the study concludes and highlights the limitations of the study in section 8.

2. Theoretical background

2.1 Small-Scale Manufacturing Sector in India and Reason for selecting small scale sector for the study

The small-scale sector has emerged as a dynamic and vibrant sector of Indian economy. According to the Micro, Small and Medium Enterprises Development Act, 2006, ‘small-scale enterprises are undertakings having investments in fixed assets in plant and machinery whether held on ownership terms or by lease or hire purchase not exceeding `50 million (MSMED Act, 2006). The small-scale sector has played an important role in the industrial development, economic growth and distribution of income in the country. It has performed a vital role in the mobilization of capital, generation of employment and minimization of regional disparities of income and value addition (Sardana and Dasanayaka, 2007). As reported by annual report of MSME 2018, Micro, small and medium enterprises (MSMEs) are at the heart of industrial activity in India. There are more than 63 million MSMEs, which account for 45% of industrial production, 30.5% of services sector and employ close to 110 million people, thus making it second largest employment generator after agriculture. The MSME sector contributes 30% to GDP; India is aiming to increase this share to 50% of GDP. MSMEs are vital in generating employment, output and exports, as this sector contributes one-third to India's manufacturing output and 45% to exports. A major advantage of the small units is their very low capital-output and capital-labor ratios. This means that capital investment required per unit of output and per unit of employment is very low. This is of particular importance to a labor abundant and capital scarce economy like India (Chakrabory et al., 2019).

Though the development of small-scale sector has been an important component of India's industrial policy over the last five decades, the sector has been suffering because of many factors. The main reasons include inadequacy of working capital, lack of support from financial institutions, lack of technological support, poor leverage to deal with suppliers, lack of managerial expertise, problems related to non-availability of raw materials, inadequate demand and marketing problems, erratic power supply, labour problems, infrastructural constraints, inadequate attention to R&D and inability to face growing competition (Sardana, 2001; Sardana, 2004; Dasanayaka and Nelson, 2007).

The aftermath of 1991 (introduction of globalization and liberalization policies by the Indian government) has impacted the small-scale sector in the country in a major way (Bargal et al., 2009; Lahiri, 2012). The key elements of Indian policy for small-scale industry, which included small-scale industry reservations, fiscal concessions by way of lower excise duties, preferential allocation of and subsidization of bank credit, and preferential procurement by the government, have ceased to be operative. Quantitative restrictions have been entirely removed effective from 2001-2002, thereby permitting large enterprises (both foreign and domestic) to produce and to import to India (Mohan, 2001). Cheaper imports are available from large multinationals which enjoy the benefits of economy of size. Even the domestic large-scale industry which sourced for parts, components, and finished products from this sector is switching over to foreign manufacturers from China, Hong Kong, Thailand, Malaysia and Taiwan (Sardana and Dasanayaka, 2007).

The over-dependence of small-scale firms on external technology acquisition has rendered their available technologies and skills inefficient and outdated. Thus, there is a need to evolve their strategic technology development program for core competency building in the small-scale manufacturing industry.

2.2 Barriers to innovation in Small-Scale Industries

Small-scale industries employ large workforce and have a greater role to play in economies of a nation. However, in spite of being so important, small-scale industries are often marred by many barriers which hamper innovation activities (Demirbas, 2010). Many barriers are identified in previous literature, some of which are lack of technology adoption, cost of finance and restricted access to finances, lack of access to transfer of R&D, rapid changes in technological environment, uncertain future of technology, uncertain demand for new innovative products; lack of experience in creating and handling new technologies; lack of qualified personnel (Piattier, 1984; Carayannis et al., 2006; Madrid Guijarro et al., 2009; Tidd and Bessant, 2009; Coad et al., 2016). These barriers necessitate the development of a comprehensive model to overcome them and provide a framework for technology development of small-scale industries.

2.3 Manpower Competence and Management Commitment

Literature highlights that top management support and skills of employees are the determinants for the success of technology development initiatives of small-scale manufacturing organizations. The difference between success and failure of organizations lies in hiring the right talent and obtaining the right mix of the workforce (Harney and Dundon, 2006; Paauwe and Boselie, 2005; Baptista Nunes *et al.*, 2006; Rastogi et al., 2018). The innovative workforce is selected, given training, empowered and encouraged to participate in all activities of the organization. Top management incorporates various strategies to retain talent which includes realistic goals, effective planning, and proper performance appraisal, developing new learning systems, suitable guidance and mentoring (Wang *et al.*, 2007; Neely, 2009). The important issues in this area includes the availability of skilled workforce, educational level of employees, training of employees, availability of scientific manpower, effective reward structure/system and reaction to project failures.

Both technology use and innovation increase the need for highly skilled employees. High-tech firms striving to succeed and trying to beat competitors through being first in the market with new products strive to improve quality of their products, acquire skilled, experienced and educated workforce that can adapt to their requirements (Baldwin and Da Pont, 1996). A key feature of a successful and competitive organization is their highly skilled workforce that leads to sustain the growth of the organization (Sternberg *et al.*, 1997; Aderemi *et al.*, 2009). Continuous knowledge upgradation and skill enhancement are needed to sustain competition and, organizations competitive and technological development. People with strong educational background and enough experience are more adaptive to technological changes and are well versed with the skills required to enhance organizational productivity and thus, organizations need to focus more on continuous development and educational programs of employees (Carmen, 2008). Educated employees increase the chances of setting new businesses, developing new products, and increases the sales growth rates of emerging firms (Charney and Libecap, 2000). Communication and team related skills are also important as technical and task-related skill for higher performance of organizations (Leede *et al.*, 2002). Education is linked to higher entrepreneurial performance and productivity (Lange *et al.*, 2000; Dickson *et al.*, 2008). Training of employees is a quicker method to acquire requisite skills due to the well-structured and balanced instruction plans and methods followed to train employees according to the goals and requirements of the job and to meet specific targets of organizations (James and Roffe, 2000). Innovative organizations in order to meet their goals continually create a conducive working and learning environment in their organization and continuously update their skills (Arad *et al.*, 1997; Goncalo and Staw, 2006). Effective rewards through an in-house reward system propel employees to take risks, think differently/innovatively and, work efficiently thereby enhancing productivity. Rewards for employees can include any kind of appreciation, be it a promotion, financial incentive, some bonus or freedom to perform creatively. Whatever form an award might take (peer recognition, banquet, plaque, letter of appreciation etc), its very existence can galvanize employee contributions (Koning, 1993; Kiran and Jain, 2010; Mazzei et al., 2016). Creative ideas often mean taking risks such as implementing any new idea that deviates from the traditional work practices (Tesluk, 1997). New ideas challenge job security, cause a disturbance in normal routines and sometimes come with other employees' resistance. Too much control by top management limits creative thinking and risk taking ability among employees (Judge *et al.*, 1997; Mazzei et al., 2016). Organizations need to create an enabling environment for its employees to think creatively, experiment new things, discuss new ideas and try to implement these ideas without the fear of failure. Employees tend to work more creatively without any fear of failure and punishment.

2.4 Technology Infrastructure

New technologies are emerging at a rapid pace globally and require supporting infrastructure (Best and May, 1997). Organizations need adequate financial support, manufacturing facilities, skilled personnel, and material to carry out innovations (Amabile *et al.*, 1996; Ghorbani and Bagheri, 2008; Filipescu et al., 2013; Kusi-Sarpong et al, 2018). The important issues under this key area include: resources for innovation, modernization and renovation programs, financial support for research initiatives and technology infrastructure in small units.

Resources include "an array of elements: people with necessary expertise, sufficient funds, material resources, systems and processes for work, and relevant information" (Amabile *et al.*, 1996; Pihkala *et al.*, 2002; Paradkar et al., 2015). Workers perceive the task with sufficient resources as more important and tend to work with more efforts (Amabile *et al.*, 1996; Arad *et al.*, 1997). Innovative organizations have the advantage of superior production setups and technological advancements than their competitors (Laforet and Tann, 2006). The internal capability of the organization is elevated through learning at the organization, investment in research activities, experimentations, making changes in existing products and also developing new products. All these activities require technological infrastructures such as information technology support, new production facilities and requisite manpower (Scheel, 2002; Maranto-Vargas and Rangel, 2007; Paradkar et al., 2015; Rasouli, 2018). R&D and technology development projects are often supported by modern equipment and resources (Smilor *et al.*, 1989; Bai *et al.*, 2017). Higher spending on research activities leads to significant growth in the expertise of employees which further leads to the development of new and innovative technologies (Parthasarthy and Hammond, 2002; Guariglia and Liu, 2014; Peters, 2015; Adebanjo et al., 2018). SMEs usually, generally generate implicit knowledge. Indeed any technological infrastructure that is put in place to support knowledge management must be adapted to the organization's needs and not the other way round (Egbu *et al.*, 2005; Evangelista *et al.*, 2010).

2.5 Regulatory Support

The government offers both financial and technical support to SMEs. Financial support is in the form of loan waivers, subsidized loans, tax cuts and cheaper land for setting new plants. Technical assistance includes training to employees about latest technologies, various promotion programs for their products and technological programs (Zeng *et al.*, 2010; Gupta and Nanda, 2015). Governments should remove common hurdles affecting growth-conducive environments, develop basic infrastructure, and ensure smooth functioning of its organizations (Singh *et al.*, 2008). The important issues under this include policy measures to sustain innovation, business support mechanisms and financial support to research initiatives.

Red-tapism, excessive restrictions, stringent policies and complex procedures greatly hinder SMEs growth and thus innovation. Government officials and policymakers need to formulate policies that support SMEs in their growth and development (Beaver and Prince, 2002; Hyland and Beckett, 2005). Instead of dictating policies, the government needs to act as an agent of change and participate in SMEs development (Kim, 2001; Seeman *et al.*, 2007; Jiao et al., 2015). Government offers a wide range of programs to assist SMEs such as assistance to acquire finance, training to employees, technical advice, marketing of their products and support to set up infrastructure, all these programs are collectively referred to as business support (Tambunan, 2008; Gao, 2015; Guan and Yam, 2015; Gupta and Barua, 2016). SMEs are often constrained due to limited availability of finances, inadequate resources, and infrastructure, limited technical and managerial skills. Government support SMEs in terms of financial support, direct subsidies and also through R&D support in terms of collaborative research (Rhee, 2010; Fajnzylber *et al.*, 2009; Ramsey and Bond, 2007).

2.6 Interaction with Others

Small organizations are facing stiff competition due to growing market demand and require support from external organizations to get access to more resources (Wani *et al.*, 2004; Santos, 2006). Organizations develop relationships with many other organizations in the form of networks which may sometimes include collaborations with their competitors (Kusi-Sarpong *et al.*, 2016). Networks can be described as “a form of collaborative relationships that organizations enter into with others for strategic reasons” (Fuller-Love and Thomas, 2004). Collaborations allow companies to properly explore new technologies by exploiting available resources and thus produce new innovations (Faems *et al.*, 2005). The important issues under this key component include: networking as a strategy in small units, inter-firm collaborations, industry-institute bonding and alliances with service institutes.

Small organizations can easily improve their performance at a lesser cost through networking with others (Fuller-Love and Thomas, 2004; Xu *et al.,* 2008). Innovative organizations are involved in their marketplace and also take technological and specialized advice from external sources. These organizations are well placed to face competition and also are future optimistic (Rothwell, 1991; Barnir and Smith, 2002; Beaver and Prince, 2002). Ties with others can benefit organizations in terms of new ideas, innovations, and support to run system (Mitra, 2000; Terziovski, 2003; Capaldo, 2007). Relationships with others can help small organizations to build their capabilities and resources in addition to gaining other benefits such as service and flexibility benefits (Kelly, 2007). Collaborations with large organizations is especially beneficial for small organizations in terms of access to resources and finance and also expert advice thus, enhancing their innovation capability. Large organizations sometimes help smaller ones in marketing their products at international level (Singh *et al.,* 2008; Kumar and Subrahmanya, 2010). Organizations can stay up-to-date about latest trends and technologies through collaboration with universities (Hall *et al.*, 2003; Siegel *et al.*, 2003; Hurmelinna, 2004; Feng et al., 2010). Even though it is well known that organizations need to focus on an in-house research through investment in latest technologies but also fostering strong ties with academia can help build innovation capability for these organizations to a large extent (Hofer, 2004; Hofer, 2005; Krishnaswamy et al., 2015). Research laboratories and service institute which are engrossed in path-breaking research and supply of new technologies, scientific information and market knowledge can boost the competitiveness of organizations (Dodgson and Rothwell, 1994; Betts and Santoro, 2011; Rodríguez and Nieto, 2016). Most SMEs are resource constrained both in terms of financial and material resources and overcoming these constraints requires them to enter ties with other enterprises, academia and/or R&D institutions (Freitas et al., 2013; Guan and Zhao, 2013; Hogeforster, 2014). To benefit from these, many countries all over the world have set up technology incubation centers to foster technology transfer among academia and SME's (Kharbanda, 2001; Justman and Teubal, 1996).

2.7. Research gaps and objectives

The small-scale sector in India is lagging behind in both technologically and economically, especially when compared to its Asian neighbors like China, Taiwan, and Singapore due to lack of formidable policies, strategic development pathways and limited access to resources (Gupta and Nanda, 2015). The Indian government has floated a large number of policies for the technological development of small manufacturing enterprises but these policies often fail to reach or are not implemented by small organizations due to lack of awareness and a clear pathway to follow for its implementation. Small organizations, therefore, need a strategic framework with a clear implementation path which can be followed for technological development. To the best of our knowledge, there is currently no specific study in the Indian context which has proposed a comprehensive path framework for the strategic technological development of the small-scale sector. With this in mind, this study aims to address the following objectives:

- To identify the difficulties faced by small manufacturing enterprises when attempting to initiate technological developments.
- To analyze the indigenous technology development capabilities of small-scale manufacturing industry and develop a strategic technology development program for the same.

3. Methodology of Modeling

This phase of the work presents a synthesis of learnings and outcomes of survey and case studies for their utilization through a qualitative model to evolve a technology development program for small scale industry of the region.

Qualitative modeling used in this study involved deriving expert opinions and using this along with findings of previous phases (survey and case studies) in a structured manner. For this purpose, experts were invited to participate in the exercise. The panel of experts was drawn from the participating industry and academic institutes. The detailed findings of previous phases were shared with the experts. Four main techniques for modeling of the research problem have been used in the present work. These include Options Field Methodology (OFM) and Options Profile Methodology (OPM) developed by Warfield (1979, 1982, 1990), Analytic Hierarchy Process (AHP) developed by Saaty (1980, 1986, 1990) and Fuzzy Set Theory (FST) methodology developed by Zadeh (1965).

Discussions with experts and survey of small enterprises have revealed a number of shortcomings in the working and systems of small manufacturing organizations. A number of solutions have also been suggested. It is, however, difficult to implement all the suggestions. Therefore, there is a need for a methodology to help generates alternate solutions to the problem and help in choosing a possible set of most effective solutions. To address this objective, a qualitative model has been developed in this paper using Options Field Methodology, Options Profile Methodology, Analytic Hierarchy Process, and Fuzzy Set Theory.

3.1 Rational for selecting methodology

As the objective of this research is to develop a framework for strategic technology development of small manufacturing enterprises. So, to develop an original framework a systems research paradigm is used. In a general systems research paradigm, designing or redesigning a system requires proper identification of its elements, as well as the interactions amongst them. This generic approach is fundamental to any systems modelling design. Usually, a system design is based on contextual relationship of elements within the concerned system. However, a network of heterogeneous systems may interact with each other as a system of systems (DeLaurentis and Callaway, 2004).

Here also, to develop the original framework, integration of three main methodologies is done in order to identify the various elements related to the problem and their interaction. For developing a framework in our study we require first identification of the various issues related to technology development on small manufacturing enterprises, for that we have used OFM, wherein various options related to the problem were generated and their poly-structures were also generated (refer methodology for more details). Next step for the development of framework was to generate the strategies that can help overcome the problem and achieve the goal of technology development. For that OPM is used which helps in mapping the various curse of actions/strategies with the various profiles generated in first phase. Also. AHP is used to rank the various sub-goals for achieving the overall goal of strategic technology development in small manufacturing enterprises.

3.2 Options Field/ Options Profile Methodology

Qualitative modeling begins with listing to options using modified idea writing as a solution to the present research problem. The list of options is converted into a conceptual design. Options Field Methodology (OFM) and Options Profile Methodology (OPM) are largely used as a basis for this purpose. These techniques provide means for the thorough development of the design situation, descriptions and design target description. They involve discovery and identification of multi-dimensionality of the situation and facilitate the matching of the dimensionality of the target with the dimensionality of the design situation (Warfield, 1979; 1982; 1990).

3.2.1 Options Field Methodology

The main steps in Options Field Methodology (OFM) are as follows:

a) *Construction of a Polystructure*
b) *Initial Structuring*
c) *Naming the Categories*
d) *Identifying the design Dimensions*
e) *Discovering Clusters of dependent dimensions*
f) *Establishing a choice-making sequence for clusters*
g) Sequencing dimensions within clusters
h) *Displaying the completed Options Field*

3.2.2 Options Profile Methodology

The next technique used in the qualitative modeling is Options Profile Methodology (OPM). It comprises of the following main steps:

a) Deciding various courses of actions (profiles) of the design. These profiles represent alternative approaches which can be employed to meet various dimensions of the research problem.
b) Assigning options from options fields to profiles. This step involves generation of complete options profiles by deriving options from each cluster.

Options Profile visually represents various alternatives among chosen options with at least one option selected among the various dimensions created in OFM. A line is used to designate the option selected, and is drawn from bullet towards the tie line at the bottom. One can create many options profile from selected options fields. Each profile is the representation of one design substitute. The sequence of options is determined in selecting various options for option field.

3.3 Analytic Hierarchy Process

The next analytical technique used in this qualitative modeling is Analytic Hierarchy Process (AHP). This methodology is used to decompose the goal into various sub-objectives and selecting the alternative for each sub-objective (Saaty 1980; Saaty and Vergas, 1982; Saaty and Kearns, 1985; Saaty, 1990). A decision problem is fragmented into a hierarchy in which each sub-objective can be taken individually for analysis. After formulating the hierarchy, pairwise comparison of various criteria is completed for computing the weights of the criteria.

The main steps involved in Analytic Hierarchy Process are as follows:

a) *Decide the 'Features of Design'*: Fragment the objective into various sub-problems (alternatives or criteria or features of design) which can be evaluated independently.

b) *Develop the 'Pairwise Comparison Matrix'*: The next step is to develop a pairwise comparison of all the criteria in the hierarchy using 9 point scale mentioned in Annexure A2.

c) *Determine weights of each alternative:* Obtain weight (relative importance to achieve the decision goal) of each alternative by using the following steps:

- Compute the sum of each column of 'pairwise comparison matrix' and divide each cell value into respective columns by the corresponding column sum (column stochastic). The resulting matrix is termed as 'normalized comparison matrix'.
- Compute the average value of each row of the 'normalized comparison matrix'. These averaged values are the resulting weights of various alternatives or features of the design problem (e.g. the average of the first row is the resulting weight of the first alternative).

d) *Check consistency of results:* An index of consistency, called *'Consistency Ratio'* is calculated to check if numerical and transitive consistency has been maintained. This step begins with the calculation of a parameter called 'Consistency Index' (C.I).

$$C.I = (X_{max} - n)/(n - 1) \quad (1)$$

In equation 1, n is the number of elements being compared; X_{max} is the largest eigenvalue, which is the sum of products of each column sum (of 'paired comparison matrix') and respective row weights (of 'normalized comparison matrix').

'Consistency Ratio' (C.R) is obtained by the following equation.

$$C.R = C.I/N \quad (2)$$

In equation 2, N is the random consistency number. Its value depends on the size of the matrix (number of alternatives under consideration). Annexure A3 provides values of random consistency number (N). The value of 'Consistency Ratio' (C.R) should be less than 10% to be acceptable. If the value is not within this range, participants should study the problem again and revise their judgment (Saaty and Kearns, 1985).

3.4 Fuzzy Set Theory

The next technique used in this qualitative modeling is Fuzzy Set Theory (FST). This technique has been used to quantify the contribution of each profile (course of action) towards various objectives (features of design) and to rank the profiles under different situations.

FST is based on the recognition that certain sets have imprecise boundaries. Fuzzy sets and sub-sets are those ill-specified and non-distinct collection of objects which doesn't have sharp boundaries and in which transition from membership to non-membership is gradual rather than abrupt. A fuzzy set is characterized by a membership function, defined as a real number in the interval (0, 1). Thus, the fuzzy set can be reduced to a crisp set by transforming memberships to extremes of the range 0 or 1 (Zadeh, 1965). In this paper, FST is used for the purpose of ranking of options profiles in an integrated form with the Analytical Hierarchy Process. Ranks of options in a group process are achieved through a dominance matrix designed for the purpose.

In order to represent the views of each of the interest group, a position matrix is prepared from the responses of all the experts in the group by giving numerical values to the qualitative assessment. An average value of each element representing the group's view is worked out by multiplying membership function value of each alternative given by the respondents with assigned weight (eigenvector weight as determined by AHP). In this way, the biasness in the matrix is eliminated. The weighted matrices for each of the interest groups are thus, determined. There is three ways to aggregate the weighted matrix viz. optimistic, average and pessimistic aggregation. The highest value among various group responses represents the optimistic value, the lowest value represents the pessimistic value and the average of all the values represents the average value.

Dominance Matrix (D) of dimensions 'n x n' is determined to display the dominance structure between all possible pairs of options. The element 'd_{ij}' is the number of features for which membership value of option 'j' dominates or is greater than option 'i'. A dash is entered for the diagonal 'd_{ij}' element. If the K_{th} column is summed, the total number of dominance of option K overall options is obtained. Similarly, if the K_{th} row is summed, the number of times the K_{th} option is being dominated by all other options is determined. Outcomes that are more favorable have higher column sums and lower row sums. In cases where an option is very close to another option on the basis of aggregate weighted position matrix, the dominance among the options exists only if the membership value of the second option is outside the specified limit. The options can be considered as equivalent with respect to that feature. This range may be set for each problem (for example ± 0.5 percent of the membership value) but should not be too large; otherwise, a lot of information is likely to be lost. As in case of weighted position matrices, three dominance matrices namely optimistic dominance matrix, pessimistic dominance matrix and mean dominance matrix are determined. The ranks of options are normally decided by examining the ranks obtained from the extent of dominance and also the extent of being dominated by other options. Although any of the optimistic, pessimistic and average approaches can be used but there are shortcomings in each. The best course of action for a decision maker in such a situation may be to use Hadley's criteria of cautious optimism (Hadley, 1967). The decision maker may choose different coefficients of optimism (α). If 'A' is the dominance weight of the option as determined from the optimistic matrix and 'B' is that of the pessimistic dominance matrix, the weight of option according to Hadley's criterion is determined by the relationship:

$$W = \alpha * A + (1 - \alpha) * B \tag{3}$$

Since the process of choosing the coefficient of optimism (α) in Hadley criterion of 'Cautious Optimism' is a judgment based approach, ranks of options from the dominance matrix are considered on the basis of dominance and ignoring the considerations of being dominated.

4. Identification of learning issues

Based on the previous literature we reviewed and discussions with experts, many issues have been identified. The reviewed literature was shared with experts and then one to one meetings with different experts through personal interviews was done. Each expert was asked to list down the issues related to strategic technology development. All the issues obtained from different experts were listed and overlapping issues were deleted to arrive at the final 114 issues.

These issues are categorized under each factor and are presented in Table 1.

[Insert Table 1 here]

5. Modeling Analysis

5.1 OFM-based Modeling

A total of 209 options were initially proposed by the experts as a solution to the present research problem. Some of these options were overlapping. After scrutinizing and combining them, we arrived at 114 independent options and the poly structure was completed. These options have been presented in the completed options profiles in Figure 1.

5.1.1 Putting the Options into Categories

These options were then put into various categories and further named. The categories are represented in Table 2.

[Insert Table 2 here]

5.1.2 Dimensions of the Design

The above categories were further reviewed to identify whether or not to include or exclude any of them for the design. After the review, all of them were included and considered as dimensions of the design.

5.1.3 Clusters of the Design

The dimensions were put into broader categories called clusters. Eight main clusters have been identified in this paper through clustering of dimensions. These clusters are presented in the next section and are shown in Figure 1.

5.1.4 Sequencing of Clusters

Following the clustering of dimensions, the clusters were put into the sequence as per the importance of an area. The sequencing of dimensions within clusters was then carried out. The resultant clusters with sequenced dimensions are given below:

1. Business Strategy for Competitive Excellence
2. Organizational Support
3. Product Innovation Strategies
4. Networking and Joining Hands
5. Policies and Directives
6. Employee Involvement and Learning
7. Market Responsiveness
8. Continuous Improvement and Development

5.2 OPM-based Modeling

In this phase of the modeling, various profiles (courses of actions or strategies) are planned to meet various dimensions of the research problem. These profiles represent alternative approaches which can be employed to achieve different dimensions of technology development at the strategic level. The details regarding different approaches are discussed as follows:

Strategic Stimulation based Approach (S_{ba}): This approach focuses on building a conducive and supportive internal environment to encourage and motivate employees for technology capability building of the organization.

Technology-based approach (T_{ba}): This approach focuses on building an adequate research infrastructure for product and process innovations.

Regulatory Environment based approach (R_{ba}): This approach emphasizes on providing a supportive policy framework for technology development programs of small-scale sector.

Nucleus-based approach (N_{ba}): This approach focuses on obtaining operational support and capabilities through alliances and interactive learning networks.

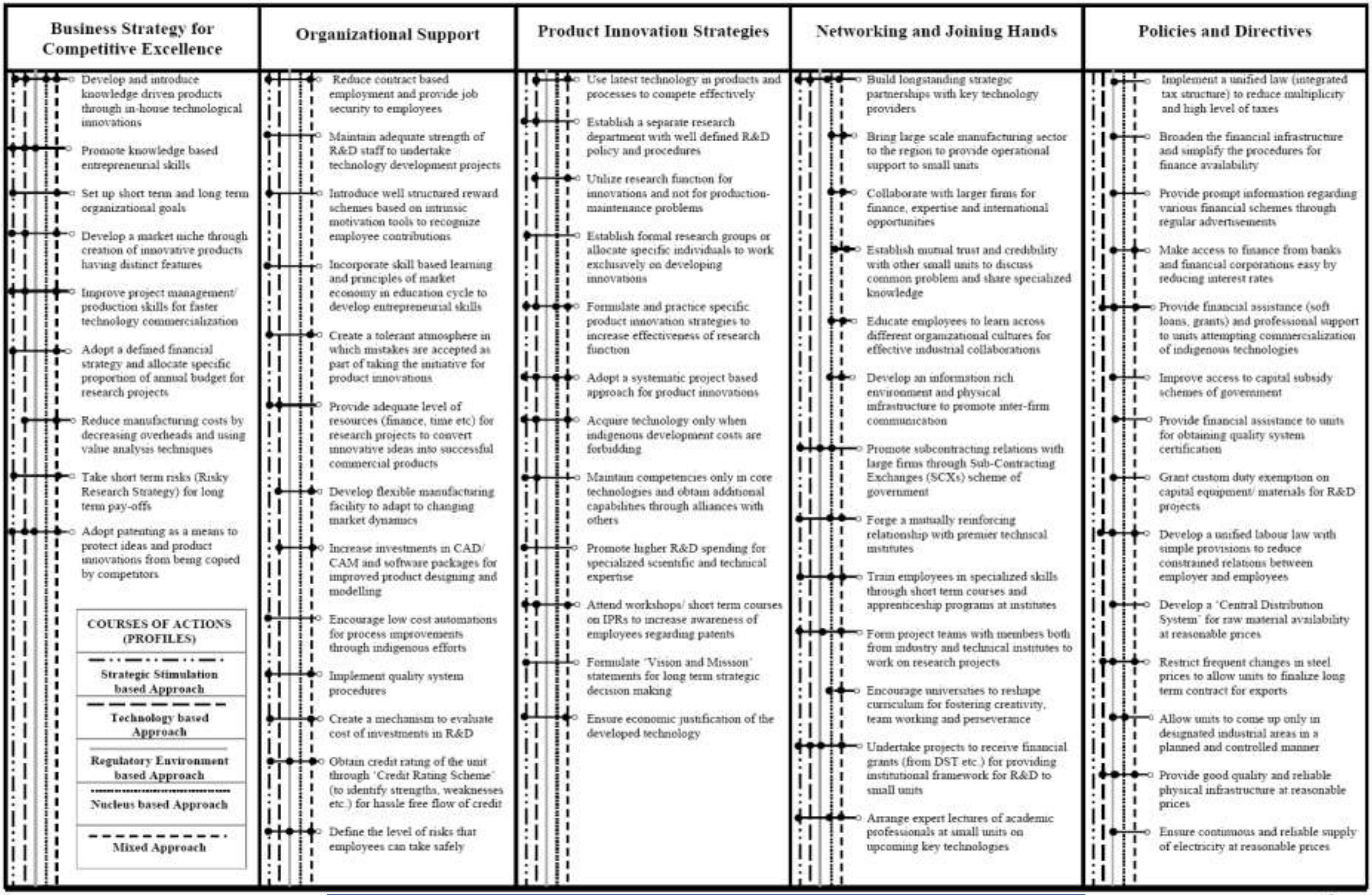


Figure 1 (a) ***Completed Options Profiles***

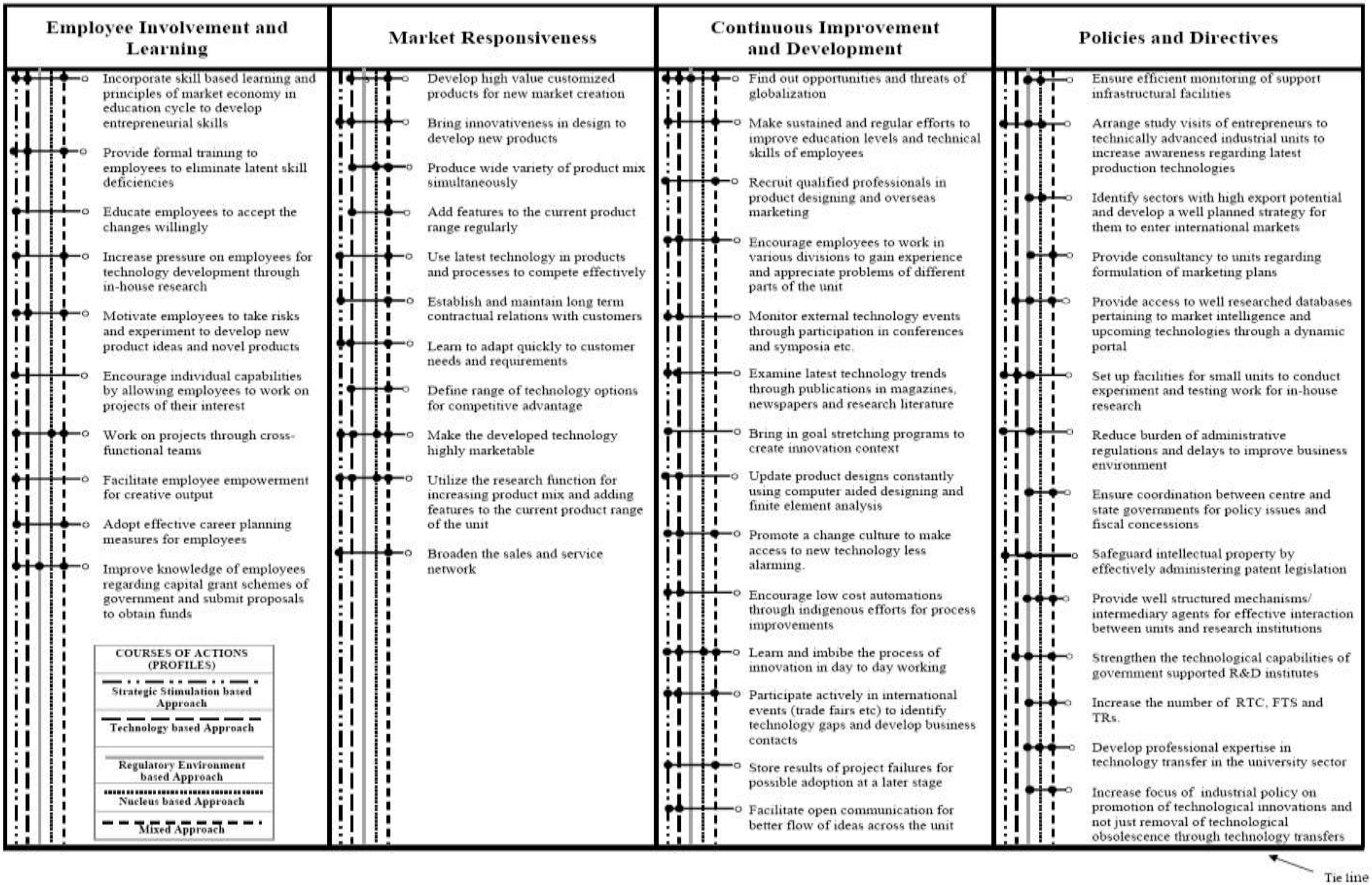


Figure 1 (b) Completed Options Profiles

Mixed approach (M_a): This approach uses a mix of features of the above profiles. It strategically utilizes the key elements of different profiles to implement the required options to meet an objective.

After deciding upon various profiles, the next task has to do with finding out the options from each cluster contributing to each profile. The completed 'options fields' have been displayed in Figure 1. A tie line has been drawn at the bottom. Each option contributing to a profile has been joined to the tie line through its bullet.

5.3 AHP based Modeling

The next step in the modeling is the use of the Analytic Hierarchy Process (AHP). Here, the decision problem (main objective of research problem) is decomposed into a hierarchy of sub-problems (sub-objectives or goals) by the experts. The sub-objectives formulated by the panel are as follows:

Goal A. To make the industry receptive (and interested) to participate in technology development initiatives through in-house research efforts.

Goal B. To develop skills of creativity and innovation among employees of small-scale industry.

Goal C. To create an environment within the industrial units conducive to technological innovations.

Goal D. To create an enabling environment in the whole industrial sector and society for technology development.

Goal E. To create a supportive policy framework to facilitate technology upgradation initiatives of the industry.

The Analytic Hierarchy Process (AHP) was employed to determine the relative weight of these sub-objectives in achieving the overall objective of technology development in the industry. Pair-wise comparison method of AHP was applied to determine the weight of each goal. Three respondents participated in the process and compared each goal with another, independently.

The respondents were purposively selected and included an industrial expert (Proprietor of Pye Tools Private Limited, Ludhiana), he is a post graduate in engineering and has over 20 years of experience; an academic expert (a Senior Professor of Industrial Engineering Department, National Institute of Technology, Jalandhar), he is a doctorate in Industrial Engineering and has more than 15 years of experience; and one senior manager of a company, with more than twelve years working experience.

The ‘pairwise comparison matrices’, ‘normalized comparison matrices’, and values of eigenvectors, obtained from the numerical ratings given by expert 1 is provided in Tables 3 & 4. The numerical ratings given by respondents were quite consistent and consistency ratio (C.I) was found well within permissible limits (less than 10%) in each case. The resulting weights for expert 1 using AHP are shown in Table 4.

[Insert Table 3 here]

[Insert Table 4 here]

Similarly, weights for all the experts were calculated as well as consistency ratio values using equation 2 but are not shown here. The weights of all experts are presented in Table 5.

[Insert Table 5 here]

The results in Table 5 depicts that, to achieve the overall objective of technology development through in-house research, it is most important to create an environment within industrial units conducive to technological innovations (sub-objective C). This objective highlights the importance of creativity and emphasizes the need for a conducive environment to foster innovation in the organization. Organizational structure should be such that it provides a mechanism for developing and sharing new ideas. Management should make strategic choices with regard to human resources and motivate employees through well-structured reward schemes (Goncalo and Staw, 2006; Kiran and Jain, 2010; Mazzei *et al*., 2016). Providing an adequate level of resources, including people with necessary expertise, sufficient funds, material resources, systems and processes for work, and relevant information are also a part of this criterion (Amabile *et al.,* 1996; Paradkar *et al*., 2015).

The next criterion in order of importance is to develop skills of creativity and innovation among employees (sub-objective B). Education and training of employees are most prominent for enhancing the competitiveness of the organization. Industrial organizations should continuously make efforts to upgrade the knowledge and skills of its workforce (Goncalo and Staw, 2006). Training and education programs should be operated extensively to identify strategies to face the competition. Small organizations should encourage its employees to utilize some fraction of their earning on training and self-development.

The next criterion is to make the industry receptive (and interested) to participate in technology development initiatives through in-house research (sub-objective A). Industrial units should realize that in this era of globalization and liberalization, survival is possible only through indigenous technological innovations (Paradkar *et al*., 2015). The industry should be open to internal changes and put more pressure on employees to undertake projects for new product developments.

The next criterion in order of importance is to create a supportive policy framework to facilitate technology upgradation in the small sector (sub-objective E). The government should create the right economic, fiscal and regulatory framework within which innovation and entrepreneurship can prosper (Beaver and Prince, 2002; Gupta and Nanda, 2015). The government should provide both technical and financial support to small units, in terms of tax incentives, tax cuts, easy loans, training to employees etc.

The last criterion in order of priority is to create an enabling environment in the whole industrial sector and society for technology development (sub-objective D). Here, the overall objective of technology development is achievable through networking and joining hands with others (Kusi-Sarpong *et al.*, 2016). This includes entering into alliances with large-scale industrial units, other small units in the region, premier technical institutes, and research establishments etc.

The results have clearly indicated that internal capability (sub-objective: A, B, and C) is decisive for product innovations to emerge from small-scale sector, whilst external support (sub-objectives D and E) only play a complementary role.

5.4 FST based Modeling

The next technique used in the qualitative modeling is Fuzzy Set Theory (FST). This stage of the modeling starts with preparation of 'position matrices'. In these matrices, the qualitative value of the contribution of each profile towards each objective (goal) is decided by experts. Again, this exercise has been done by the three respondents. The position matrix for expert 1 is presented in Table 6. From the position matrices, the 'weighted position matrices' are determined by multiplying the weight of each objective as determined earlier (through AHP approach) by the value of each position of the position matrix. The weighted position matrix for expert 1 is provided in Table 7a. From the weighted position matrices, the 'optimistic', 'average' and 'pessimistic' weighted position matrices are obtained using Fuzzy Set Theory. For the optimistic matrix, the highest value of each position is selected, for pessimistic the lowest values are selected and for the average matrix, the average values are also selected. These values are shown in Tables 7b-7d respectively.

[Insert Table 6 here]

[Insert Table 7 here]

The manufacturing sector in India is currently going through a transition phase. The presence of large multinational organizations along with many new Indian startups as well as existing organizations has led to a manufacturing revolution. India's manufacturing competency is one of the highest among the developing economies and as a result has attracted large investments. India's obligation as a member of WTO to bring down tariff and non-tariff barriers provides a competitive environment for small-scale sector. However, global competition has reached an unprecedented level and the country needs to develop its manufacturing sector in line with global leaders. The small-scale sector in the region is facing stiff competition from high-quality innovative products from Germany, China, Czech Republic, Korea and Taiwan. In such circumstances, a pessimistic approach for designing a technology development program may not succeed. On the other hand, a purely optimistic approach may also not yield desired results because of the following reasons. Small units in the region lack adequate physical and technology infrastructure. The government has formulated several schemes to facilitate technology upgradation but benefits have not reached the industrial sector because of lack of awareness and initiative of proprietors. Also, there are bureaucratic hurdles and tedious procedures involved in accessing government support. Furthermore, the current scenario in the global market in terms of economic imbalances and manufacturing recession also puts a cap on implementation of a purely optimistic approach. In such situation, a cautious optimism approach with a relatively high degree of optimism may be employed.

Using equation 3, Hadley's matrix is calculated under various levels of optimism. Hadley's matrix for 80% optimism is shown in Table 7e, and matrices computed at various degrees of optimism have been compiled and the results are presented in Table 8. The results present the preferred strategies for achieving various sub-objectives (goals) under specific levels of optimism situation.

[Insert Table 8 here]

The following observations have been outlined in Table 8.

- To make the industry receptive (and interested) to participate in technology development initiatives (Goal A), 'regulatory environment based approach' (R_{ba}) shows maximum contribution under various conditions of optimism. The government has been imploring enterprises of all kinds to embrace technological innovation as a matter of survival in the globalized, knowledge economy. A favorable regulatory environment helps in raising the awareness of benefits of innovation and adopting a progressive strategic management practice for technology upgradation. Also, to meet this objective, it is important that various (small scale) industry associations put pressure on manufacturing organizations to join hands and work in mutual collaborations for technology development. Thus, ‘nucleus based approach’ (N_{ba}) also significantly influences this objective.

- ‘Strategic stimulation based approach’ (S_{ba}) and ‘technology-based approach’ (T_{ba}) primarily influence the development of creativity and innovation skills among employees (Goal B) and facilitate in creating an environment conducive for technological innovations (Goal C). Innovative firms have a positive plan of action towards employees training and development to achieve long-term goals of the organization.
- ‘Regulatory environment based approach’ (R_{ba}) and ‘nucleus based approach’ (N_{ba}) are the preferred strategies to create an enabling environment in the whole industrial sector and society for technology development (Goal D).
- To create a supportive policy framework for facilitating technology upgradation initiatives of industry (Goal E), ‘regulatory environment based approach’ (R_{ba}) is the most preferred strategy. It is the government that has to design and formulate an encouraging policy framework for small-scale sector. The benefits of government schemes can reach industrial units only through awareness of proprietors and active participation of employees to access support through these schemes. Thus, ‘strategic stimulation based approach’ (S_{ba}) is also required to meet this objective.

The next step is the preparation of dominance matrices under different situations of optimism. Dominance matrix indicates the dominance of each course of action over its counterparts in meeting various criteria under a given condition of optimism. The cell value (numerical value entered in a cell for comparing two profiles) in the dominance matrix signifies the number of criteria in which one course of action dominates over the other. In the matrix, a profile written on the top dominates the profile written on the left. The column sum in each matrix helps in ranking the various courses of actions. The higher the column sum of a given course of action (profile), the more dominance it is over other profiles under a given situation.

The dominance matrices under conditions of pure optimism, pure pessimism, and average optimism are presented in Tables 9-11.

In the optimism dominance matrix (Table 9), ‘regulatory environment based approach’ has emerged as the most preferred strategy for achieving the overall objective of technology development in small-scale sector. ‘Strategic stimulation based approach’ and ‘mixed approach’ have occupied the second and the third positions respectively.

[Insert Table 9 here]

For a completely pessimistic situation, the ‘mixed approach’ is the most preferred situation followed by ‘strategic stimulation based approach’ and ‘regulatory environment based approach’ respectively.

[Insert Table 10 here]

The average dominance matrix shows ‘mixed approach’, as the most preferred strategy followed by ‘regulatory environment based approach’ and ‘strategic stimulation based approach’ respectively.

[Insert Table 11 here]

Similarly, dominance matrices for various degrees of optimism (80%, 60%, 40% and 20%) have been calculated and dominance matrix for 80% optimism is presented in Table 12. The results of all these dominance matrices have been summarized in Table 13.

[Insert Table 12 here]

[Insert Table 13 here]

In the present work, a cautious approach with a high degree of optimism has been considered as most appropriate. Thus, dominance matrix with 80% degree of optimism has been considered as providing the most realistic industrial situation in the region (*shaded area in Table 13*). This dominance matrix has been used to identify preferred strategies for meeting the overall objective of technology development in small-scale sector.

6. Modeling results and discussion

The results indicate that ‘mixed approach’ is the most preferred course of action to solve the present research problem. ‘Strategic stimulation based approach’ and ‘regulatory environment based approach' have occupied second and third positions respectively. 'Technology-based approach' and 'nucleus based approach' are considered the least preferred profiles.

To sum up, the following three strategies in order of their importance have emerged as significant to meeting the objective of technology development through in-house research initiatives in small-scale sector.

1. Mixed Approach
2. Strategic Stimulation based Approach
3. Regulatory Environment based Approach

6.1 Mixed Approach

The results of the qualitative modeling clearly show that to facilitate technology upgradation in the industrial sector, the most preferred strategy is 'mixed approach'. This strategy has also emerged as the second most preferred profile to meet the majority of the sub-objectives (Goal A, Goal B, and Goal E) of the research problem. For the remaining two criteria (Goal C and Goal D), 'mixed strategy' is ranked third.

'Mixed Approach' signifies that to meet the overall objective of technology development in small-scale sector, a judicious mix of several courses of actions is required. Though, pure strategies (i.e. strategies other than the 'mixed approach') have been most beneficial in achieving specific sub-objectives but to achieve the overall objective, 'mixed approach' has shown maximum contribution. Managing the strategic implementation of technology development program from a current state to the desired future condition is a complex process. The various goals and objectives must be fully understood and integrated into the strategic and business plans of the organization. To enhance the probability of success through such initiatives, a structured approach has to be employed. For this, performance evaluation is based on multiple inputs and multiple outputs. Since evaluation involves multiple inputs and outputs, it is a multi-criteria decision problem. Pure strategies have been effective in meeting the individual criterion, but the overall objective of technology development of small scale organizations through in-house research needs elements of various profiles and hence the 'mixed approach'.

6.2 Strategic Stimulation based Approach

‘Strategic stimulation based approach’ has emerged as the second most preferred strategy for meeting the overall research objective. It is also the most preferred profile to create an environment within industrial units conducive to technological innovations (Goal C) and to develop skills of creativity and innovation in employees (Goal B). However, for the remaining criteria (or sub-objectives), this approach has not shown a significant contribution.

‘Strategic stimulation based approach’ focuses on building a conducive internal milieu which encourages employees for technology capability building of the small scale organization. It stresses on having appropriate systems and procedures which emphasize that creative effort is a top priority within the small scale organization and an environment where employees are free to develop, try and share new ideas. This supportive environment can also help to keep knowledge and skills of employees updated if combined with regular training. Providing training to develop operative and intermediate level skills is also a crucial constituent of this strategy (Baldwin and Da Pont, 1996; Carmen, 2008; Aderemi *et al.,* 2009). It also focuses on developing multi-skilled workforce of small scale organization through job rotation programs to perform varied tasks.

The approach emphasizes the need for making strategic choices with regard to human resources. Industrial units should explicitly strive towards the attraction, development, and retention of creative talent and engage employees who are willing to take risks and employ innovative thinking and ideas in the organization. Providing job security and better career planning measures are also important constituents of this strategy.

‘Strategic stimulation based approach’ emphasizes the need to have in-house reward systems to recognize contributions of employees. An efficacious reward system encourages employees to perform at higher efficiency and take risks to develop new ideas and products within small scale organization. With ‘strategic stimulation based approach’, extrinsic rewards (i.e. increased wages, incentives, options to buy shares etc.) have to be given at lower worker level to ensure parity in pay and encourage workers by providing them substantial earning options (Kiran and Jain, 2010; Mazzei *et al*., 2016). Beyond the base salary thresholds, innovation in small scale organizations is primarily driven by intrinsic motivation (increased autonomy and improved opportunities for personal and professional growth).

The approach stresses that there should be freedom to experiment and to challenge the status quo. Companies should build an environment where they can tolerate the mistakes of its employees while trying some innovative ideas. Individual capabilities should be encouraged by allowing employees to work on projects of their interest. Employees should optimally utilize their time to spend on other activities like innovation development without sub-optimizing their routine activities.

Research department should be established as a separate division in small organizations working with a clearly defined policy and specific product innovation strategies. Manufacturing units should develop a market niche by the creation of innovative products having distinct features (Paradkar *et al.*, 2015; Bai *et al.*, 2017). They should offer a wide variety of product mix simultaneously and should add features to the current product range regularly. Finally, 'strategic stimulation based approach' emphasizes on establishing and maintaining long-term contractual relations with customers.

6.3 Regulatory Environment based Approach

The results of the qualitative modeling indicate that 'regulatory environment based approach' is the third most preferred strategy for achieving the overall objective of technology development in small-scale sector. This strategy is also the most preferred profile for meeting the majority of the sub-objectives of the research problem. Thus, to make the industry receptive (and interested) to participate in technology development initiatives (Goal A), to create an enabling environment in the industrial sector and society for technology development (Goal D), and to create a supportive policy framework for facilitating technology upgradation initiatives (Goal E), 'regulatory environment based approach' has shown maximum contribution.

'Regulatory environment based approach' focuses on creating the appropriate financial and regulatory model so as to support entrepreneurship growth. It stresses the need to continually examine the policies, regulations, and laws to check if these policies corroborate or hinders innovation process. It emphasizes on the need for implementing a unified law for small organizations to reduce multiplicity and high level of taxes. It also accentuates to develop a unified labor law with simple provisions to reduce constrained relations between employer and employees of small units (Hyland and Beckett, 2005).

The approach focuses on government's role in providing reliable and high-quality physical infrastructure at reasonable prices. It emphasizes that small organizations should be setup at spate designated location so as to monitor their working and infrastructural facilities. The private sector should be involved in the development and management of infrastructure and there should be the provision of services on payment. The government should ensure availability of raw materials at reasonable prices and restrict frequent changes in prices to allow units to finalize long-term contracts for exports (Seeman *et al.*, 2007; Jiao *et al*., 2015). The strategy also focuses on bringing large-scale manufacturing sector to the region to provide operational support to small units. Furthermore, there should be proper coordination between the center and state governments regarding regulatory obligations being imposed and financial benefits being offered by other states.

'Regulatory environment based approach' stresses on the need of broadening the financial infrastructure, simplifying the procedures for finance availability, providing prompt information regarding various financial schemes, and making access to finance easy by reducing interest rates and collateral requirements. Resources (grants, soft loans) and professional support should be provided to manufacturing units attempting commercialization of indigenous technologies (Gupta and Barua, 2016).

'Regulatory environment based approach' seeks to provide direct and practical support in the execution of innovative projects and successful exploitation of their results by effectively administering the patent legislation. It stresses on increasing government investments in universities to enhance industrially-relevant research/ training and provision of well-structured mechanisms for effective interaction between industrial units and research institutions.

'Regulatory environment based approach' requires the government to act as an enabler of growth and change by working in coordination with all the stakeholders like small units rather than forcing policies on them.

7. Development of a Conceptual Framework

This section discusses the development of a conceptual framework representing main elements of the technology development program for the small-scale industrial sector. It represents the linkage between essential components of technology development program and elaborates on their relative contribution in meeting the overall research objective. The framework is presented in Appendix A.

The key inputs (Technology Inputs Success Factors) and output performance parameters (Development Indicators) have been shown in the conceptual model. 'Technology Input Success Factors' is the independent research constructs and 'Development Indicators' are the dependent constructs of the decision problem.

The model also depicts the overall objective of research problem having decomposed into a hierarchy of sub-objectives or goals. It further represents the relative weight of these sub-objectives in achieving the overall research objective. For this, the sub-objectives have been shown in varying intensities of color, where the darkness of color represents the higher weight of a sub-objective in meeting the main objective of technology development in small-scale sector.

Finally, the conceptual framework presents different profiles or strategies which can be used to meet various dimensions of the research problem. The model depicts the relative contribution of each profile in meeting different sub-objectives and also the overall objective under the realistic situation (of a high degree of optimism, 80%). The contribution of profiles has been represented with the help of vertical arrows (vertically upward and colored arrows). The length of an arrow signifies the extent of the contribution of a strategy in meeting a goal. The greater is the length of an arrow for a given goal; the higher is the relative contribution of the profile it represents, in meeting that goal.

The conceptual framework indicates that to meet the overall objective of technology development in the small-scale sector, 'mixed approach' has shown maximum contribution and hence is the most preferred strategy.

8 Practical Implications

Amongst the several problems faced by small scale manufacturing organizations in the region, technological obsolescence is one major predicament. The industry, in general, still lacks in an innovative environment in terms of infrastructure as well as policy support. It is appropriate to incorporate schemes in the existing policy and institutional network to provide technical and financial assistance to in-house technological innovations at the district levels and make it easily accessible to small scale industrial units. There is a need to create 'research and development fund' at the state levels for disbursement as margin money through District Industrial Centres (DICs) to small units for encouraging them to undertake formal R&D and technological innovations. Further, government should provide funds to engineering institutes which could provide institutional infrastructure for R&D or undertake development projects for small units at the regional level. However, it needs to be emphasized that technological transformation of the industrial sector is an enormous task and the government alone can not achieve the objective, however gigantic its infrastructure may be. Internal capability is decisive for product innovations to emerge from the industrial sector. External support can only play a complementary role. Therefore, major initiative has to come from industry itself, particularly through industry associations. The importance of 'achieving and sustaining competitiveness in the long run' and 'investing self-efforts and resources' needs to be realized by the industry. This will play a crucial role in their long term development in future.

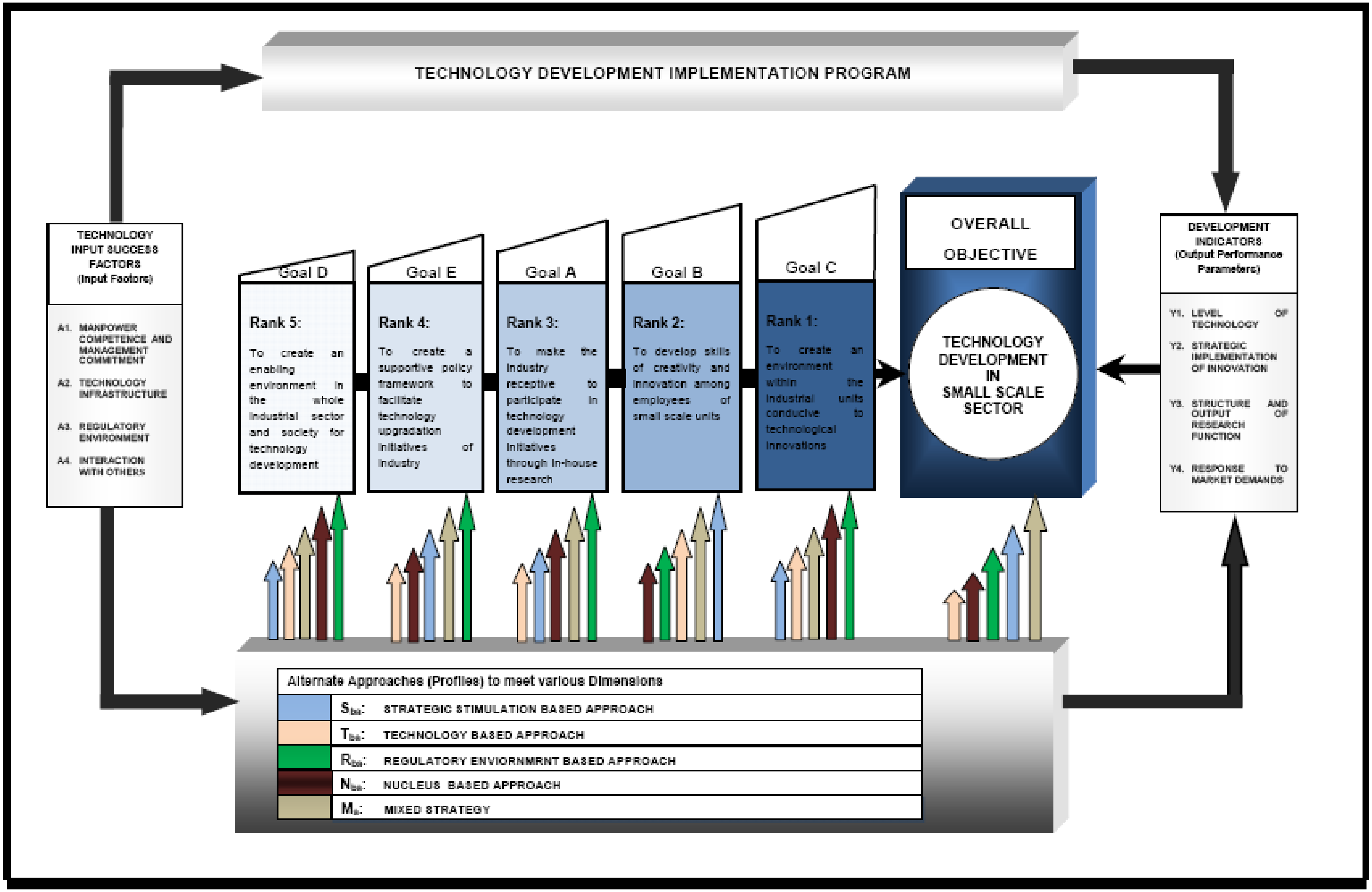
9 Conclusion, Limitations and Future Scope

Manufacturing firms globally are faced with immense technological, social and economic pressures as a result of trade liberalization and globalization. The worst victims amongst these are the small enterprises especially those from emerging nations such as India due to their limited capability and resource base. Indian government have initiated many policy frameworks to support technological development but failed or are not implemented due to the lack of awareness and a clear pathway for implementation. Small enterprises, therefore, need a strategic path framework to be followed for technological development.

To achieve the overall objective of technology development in small-scale sector, a management process has been developed using qualitative modeling in the present work. Qualitative modeling involved deriving expert opinions and using this along with findings of previous phases (outcomes of survey and case studies) in a structured manner. Four main techniques were used for this purpose. The first technique called options field methodology generates a list of options as a solution to the present research problem. It places the options into a set of categories and develops suitable names for each category. It further identifies the dimensions of the target and puts them into various clusters. This is followed by sequencing of clusters and sequencing of dimensions within clusters. Finally, the completed 'options fields' are displayed. In the present work, 114 options were generated. The next technique used is options profile methodology. Here, various courses of actions (profiles/ strategies) of the design are developed which can be employed to achieve the overall objective of the research problem. In this present work, five different profiles was developed using this technique. These included, '*strategic stimulation based approach*', '*technology-based approach*', '*regulatory environment based approach*', '*nucleus based approach*', and '*mixed approach*'. The various options generated through options field methodology are then allocated to these alternate profiles to complete the 'options profiles'. The completed options profiles represent alternative approaches and courses of action to be adopted under each. The next technique used was the analytic hierarchy process. It decomposed the decision problem into a hierarchy of five sub-problems and determined their relative weight in achieving the overall research objective. The fourth technique used for the qualitative modeling was fuzzy set theory. This approach was used to quantify the contribution of each profile towards each objective and to rank the various profiles under different situations. For this, position matrices and weighted position matrices were formulated. The weighted position matrices have been aggregated in three ways: optimistic, average and pessimistic aggregation. Following this, dominance matrices were formulated to display dominance structure between all possible pairs of profiles. Based on these matrices, the ranks of various profiles under different situations of cautious optimism were determined.

In this present work, a cautious approach with a high degree of optimism was considered as most appropriate. Thus, dominance matrix with 80% degree of optimism was considered as providing the most realistic industrial situation in the region. The results have indicated that a ‘mixed approach’ is the key strategy to solve the present research problem. ‘Strategic stimulation based approach’ and ‘regulatory environment based approach’ have occupied the second and third positions respectively. ‘Technology-based approach’ and ‘nucleus based approach’ were considered the least preferred profiles.

The paper, like any other study, does have some limitations. Among these limitations is the use of only qualitative modeling techniques including OPM, OFM, AHP, and FST for investigating the subject. It is recommended that future studies such consider ‘pure quantitative mathematical’ modeling approach for the validation of results using statistical tools such as structural equation modeling. The use of three experts (respondents) and manufacturing sector from only one region (India), making it difficult to generalize the results is another limitation of this study. Yet, given the diversity of the respondents, study can be very certain about the concerns and activities that relate to technological development within the India manufacturing organizations and the sector at large. But, is it clear that more and broader studies are needed. Furthermore, to compute weights of each goal, the AHP technique was used. Other multi-criteria decision-making techniques such as Shannon-Entropy and best-worst method (BWM) techniques can also be used to validate the AHP results. Also, techniques like Genetic algorithm and particle swam optimization can be used to compare results and develop new findings. It is clear that research on technology developments in small enterprises in emerging economies is a subject that merits and requires further study. In our view, this study helps to lay a strong foundation for a further and future study on this important topic.



Appendix A. Conceptual Framework

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Appendix A1

Literature for comparing key factors identified for innovation in Small scale sector by different authors

Authors	**Key factors of innovation**

Kumar and Subrahmanya (2010)	Firm owners capabilities; Inter firm linkages
Konsti Laakso et al. (2012)	Absorptive capacity; Organizational structure and culture; Leadership; Individual creativity
Parrilli and Elola (2012)	Process of R&D; Strategy of technology acquisition and development; Collective creativity; Teamwork; Communication policy
Tomlinson and Fai (2013)	Product innovation; Process innovation; R&D expenditure; Cooperation with buyers; Cooperation with suppliers; Cooperation with competitors
Krishnaswamy et al. (2014)	Entrepreneurial motivation; New product development; Technical qualification; R&D teams
Gupta and Nanda (2015)	Entrepreneur role; Regulatory corroboration; Technology infrastructure; Linkage capability
Love and Roper (2015)	Skill, leadership and people management; R&D; Capital investment and equipment; Internal financing; Design; Intellectual property management; Leadership and strategy
Tavassoli and Karlsson, (2015)	Product innovations; Process innovations; Organizational innovations; Marketing innovations
Sarooghi et al. (2015)	Managerial innovations; Organizational innovations; New product performance; Implementation of ideas; Patent disclosure
Subrahmanya (2015)	Entrepreneur’s qualification; Skilled labour; Exclusive design centre; External interaction
Gupta and Barua (2016)	Entrepreneur role; Linkage capability; Technology infrastructure; Government support
Gupta and Barua (2017)	External Linkages; Entrepreneur Characteristics; Resources for Innovation; Employee related factors; Research and Development initiatives
Prange and Pinho (2017)	Managerial competencies; Technical skills; Training; Managerial risk taking abilities; Investment in advanced human resources; Developing new products/services; Capability to collaborate
Presenza et al. (2017)	External knowledge sources; Absorptive capacity
Raghuvanshi et al. (2017)	Organizational culture; idea management; Knowledge management; technology management; Actors involvement; Strategy formulation; Networking; Leadership practices; Institutional support
Castela et al. (2018)	Infrastructures; External factors; Organizational aspects; Employees; Manager

Appendix A2

Scale for Pairwise Comparison

Judgment of Preference (Definition)	**The intensity of Importance (Numerical Rating)**
Equal Importance	***1***
Moderate Importance	***3***
Strong Importance	***5***
Very Strong Importance	***7***
Extreme Importance	***9***
Intensities of* ***2*, ***4, 6***, *and* ***8*** *can be used to express intermediate values*	

Appendix A3

Value of Random Consistency Number

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency Number	**0.00**	**0.00**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.49**