Flexible Systems Management

Sushil
T.P. Singh
Anand J. Kulkarni *Editors*

Flexibility in Resource Management

Springer

Flexible Systems Management

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Preface

The changing landscape of business is influencing the enterprises to be more flexible and agile. Flexibility in any enterprise is reflected at various levels such as strategy, structure, systems, and resources. Every organization possesses a variety of resources such as innovation capabilities, people, technology, and finance, among others. These resources can be effectively utilized by managing them in a flexible manner. This also requires carrying out the valuation of flexibility initiatives on multiple fronts so as to select and implement them for high-value creation for the organization.

The chapters in this book are selected from the papers presented at GLOGIFT 15 (15th Global Conference on Flexible Systems Management) held at Symbiosis Institute of Technology, Symbiosis International University in October, 2015. Nearly 90 research papers were presented by academicians as well as practitioners in this conference. The participating authors were from various parts of India, USA, Singapore, Australia, Hungary, and Japan. The research papers were subjected to a stringent peer review. The selected papers presented at the conference were again reviewed and further developed and organized in the form of an edited volume that could serve as a good reference material in the area of flexibility in resource management.

The selected chapters covering various issues related to the theme of flexibility in resource management are organized into following four parts:

I: Flexibility and Innovation
II: Flexibility in Organizational Management
III: Operations and Technology Management
IV: Financial and Risk Management

Part I deals with the core issue of flexibility, its valuation, and innovation measurement consisting of three chapters. Chapter 1 deliberates on the need and framework for valuation of flexibility initiatives. The benefits of flexibility define its worth, which in relation to the associated cost gives its value. The chapter gives an overview of flexibility initiatives in organizations with real-life case examples. It

proposes a basic model for flexibility valuation and illustrates it in the context of select flexibility initiatives such as variable capacity, multi-skilling, and flexi-time/flexi-place. It compares these initiatives on multiple criteria and also gives different valuation plans. Chapter 2 discusses and explores the factors of flexibility in product family engineering (PFE) process. It identifies strategic intent, resources, and flexibility as important enablers in this process. It has taken the factors such as retained earnings, R&D spending, total assets, and number of employees to develop a total interpretive structural model for enhancing the PFE flexibility in organizations in information technology sector. Chapter 3 highlights mobilization and allocation of resources to encourage innovations in higher education system. It considers various factors that are institute- and location-specific which drive the outcomes. It presents the step-by-step development of a total interpretive structural model of innovation performance, which will be useful to both policy makers and academicians.

Part II consisting of four chapters covers different facets of flexibility in organization management such as flexible adaptation, knowledge management, work place diversity, and workplace spirituality. In Chap. 4, the cause-and-effect relationship between the networked elements of the supply chain network and its behaviour is analyzed. The strong analogies between the supply chain network and the biochemical networks explained behaviours in supply chain networks. It helped further to create adaptive flexibility in the organization and increase the resilience against supply chain disruptions. In Chap. 5, the major challenge such as managing the speedy changes in technology and customer demands, which highlights the importance of flexibility, is discussed and the importance of knowledge as a strategic resource for the organizational success is well acknowledged. The techniques such as factor analysis, univariate analysis, and regression analysis have been used to develop the final framework that reflects the interrelationships among knowledge management, flexibility, and entrepreneurship. Chapter 6 is focused on organizational climate on managing demographic diversity by devising a survey questionnaire which attributes a mix of age and gender as well as education and managerial level. Overall, the study demonstrated the potential value of focusing on organizational climate to manage the demographic diversity in a way so as to get desired individual and organizational outcomes. Chapter 7 focuses on organizational and individual learning and presents a conceptual framework to elucidate how employees' experience of spirituality at workplace influences their learning attitude which in turn affects their learning commitment. A theory of reasoned action is employed to elucidate this framework. The key points such as implications for employee development, organizational development, and organizational learning are also discussed in detail.

Part III addresses management of operations and technology resources in three chapters dealing with green supply chain management, computer-aided process planning, and growth of technology ventures. Chapter 8 highlights the importance of analyzing green supply chain in power sector, considering the fact that it is one of the main polluters in developing countries. The chapter studies various drivers affecting Indian power industry using Total Interpretive Structural Modeling

(TISM). The drivers of GSCM have been studied in power companies operating in Punjab wherein modern changes are taking place, but still there is a plenty of old baggage to pull along. The drivers were finalized and a model based on hierarchy of factors has been proposed after applying TISM technique involving expert opinion and findings from the literature. Chapter 9 presents development of a knowledge base for computer-aided process planning (CAPP). Knowledge base contains a set of defining rules that the system uses for decision-making. Multi-criteria decision-making (MCDM) technique has been used to develop the knowledge based rules for part family. A masterpiece of a family is considered, which includes all operations used by family members. This approach will be useful in linking CAD and CAM in an automated manner and thereby optimizing the use of resources. Chapter 10 analyzes the role played by management of technology (MoT) in venture scale-ups by comparing two cases of IIT Bombay high-tech ventures. The chapter identifies the factors related to the effect of MoT on the growth of ventures and presents an exploratory study via primary research to understand the characteristics and the relationships among different factors which influence a venture's growth. A comparative analysis of the companies included in a study of performance considering select criteria of international competitiveness was carried out with the aim to identify factors and criteria and to develop indices based on which multiple ventures can be compared and analyzed. This would enable new ventures to gain clarity in understanding the factors which differentiate venture scale-up.

Part IV covers different dimensions of financial and risk management. It consists of three chapters covering financial flexibility through share repurchases, portfolio selection, and mitigation of supply risk. In Chap. 11, the central concern of financial flexibility is brought out for effective capital management. It deals with such kind of flexibility to respond to fluctuations in stock prices and investment opportunities through share repurchases. The undervaluation and signaling hypotheses have been supported by the findings presented in the chapter. Other motives such as reducing agency costs, wealth transfer, and capital structure adjustment have also received empirical evidence. Chapter 12 provides a measure to identify and select investment worthy stocks named as Relative Financial Performance Indicator (RFPI). This indicator is derived by applying principal component analysis–data envelopment analysis approach, which uses financial ratios as input and output parameters. Firms having RFPI score of one are considered for portfolio construction. The results obtained can be used to benchmark with the firms that are best within the industry. Chapter 13 presents a flexible scenario building approach to mitigation of supply risks on the shop floor. Intuitive scenario modelling as a flexible proactive approach encourages the people in the organization to think about the worst possibilities in future, and be ready with mitigation plan options and thus be more productive. It is illustrated with an example of a pharmaceutical company having manufacturing plant in India.

It is hoped that this edited volume on Flexibility in Resource Management will provide a useful resource for a variety of audiences such as management students

and researchers, practicing business managers, consultants, and professional institutions.

Finally, we would like to thank all authors and reviewers who helped in shaping up this volume. In particular, we would like to thank Rejani Raghu who provided secretarial support to communicate with authors and reviewers as well as helped to format the final manuscript.

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Dr. T.P. Singh is Dean of the Faculty of Engineering and Director of Symbiosis Institute of Technology, Symbiosis International University, Pune, India. He has more than 27 years of teaching and research experience and 10 years of industrial experience. He has held the positions of Professor and Head of the Mechanical Engineering Department, Dean of Academic Affairs, Dean of Resource Planning and Generation, Director of the CII-TDB-T NET and Acting Director of Thapar University, Patiala, India. In industry, Dr. Singh has worked in maintenance, production, and inspection functions and has been involved in various projects related to product development and process improvements. He has a large number of publications in peer-reviewed international and national journals. He has also presented papers in conferences at both international and national levels and has also been actively engaged in consultancy and sponsored research and development (R&D) projects. His areas of interest are quality systems, total quality management, lean systems, waste minimization, and Six Sigma.

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Part I
Flexibility and Innovation

Chapter 1
Valuation of Flexibility Initiatives: A Conceptual Framework

Sushil

1.1 Introduction

The cause of flexibility has been espoused by numerous researchers who deliberated on the need to have flexibility in modern day organizations. Eppink (1978) dealt strategic flexibility as coping with unforeseen circumstances by reducing the impact of environmental changes on one hand, and increase in response capacity on the other. Over a period of time the concept of flexibility evolved into managing paradox as discussed by Sushil (1997, 2014, 2015a). A specific paradox of managing continuity and change has been developed as flowing stream strategy (Sushil 2012a, b, 2013). Sushil (2014) has outlined various types of flexibilities while deliberating on the concept of a flexible enterprise and its diverse shades are discussed in Sushil (2015b). This has resulted into the framework of flexibility maturity model (Sushil 2012c, 2016a) and the theory of flexible systems management (Sushil 2016b).

Though the literature on various facets of flexibility in organizations is vast, its impact on performance has been highlighted to a limited extent (Sharma et al. 2010). The valuation of flexibility is examined by few researchers and there lies a gap in the form of a generalized framework of valuation of flexibility, which has been addressed in this chapter.

The chapter first gives an overview of flexibility initiatives in organizations with real-life case examples. It then briefly reviews flexibility valuation and proposed a basic model for the same. It illustrates this model in the context of select flexibility initiatives such as variable capacity, multiskilling, and flexi-time/flexi-place. It then

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provides different valuation plans and compares the flexibility initiatives using interpretive ranking process (IRP) and Total Interpretive Structural Modelling (TISM). TISM is used to generate weights of benefits and cost factors in view of their respective driving power.

1.2 An Overview of Flexibility Initiatives

1.2.1 Types of Flexibility

The cornerstones of enterprise flexibility are identified as strategic flexibility, marketing flexibility, financial flexibility, human resource flexibility, manufacturing/supply chain flexibility, and information systems flexibility (Sushil 2014). Some of the flexibility initiatives in each type of flexibility are given below:

Strategic Flexibility

A number of flexibility initiatives have been taken by different organizations at strategic level. Some important ones are: decentralization, multiple product–market combinations, offering solutions, mergers and acquisitions, collaborations and alliances, and so on. These strategic flexibility initiatives use different shades of continuity-change combinations. For example, telecom service providers have decentralized their operations, e-commerce companies have used multiple product–market combinations (old product-new market, new product-old market, and so on), companies like IBM have strategically changed from product-based companies to ones that offer solutions to customers incorporating both products and services.

Marketing Flexibility

Marketing flexibility deals with multiple options and change mechanisms on various elements of the marketing mix. It deals with various types of flexibilities such as product flexibility, pricing flexibility, place or distribution flexibility, and promotion flexibility. For example, dynamic pricing is used by Indian Railways to increase the fare as it comes closer to the last date and time, keeping in view the shortage of capacity. Whereas, recently the national carrier, Air India has moved to provide low rates in last 4 hours keeping in view the vacant capacity on many routes. In case of service industries like banking and tourism, mobile technology is used to provide anytime/anywhere reach.

Financial Flexibility

Flexibility in financial system relates with capital structure flexibility, investment flexibility, and so on. Flexible budgeting is being practiced by public sector undertakings to meet the changing requirements. The most common financial flexibility initiative is in the form of real options to enhance the viability of any project; particularly the R&D investments.

Human Resource Flexibility

Flexibility initiatives at work place that are linked with human resources are *in vogue* in various organizations. Some important ones are compensation flexibility, flexible leave structures, and flexi-time/flexi-place, among others. The flexi-time/flexi-place has been applied in various forms in service organizations such as consulting firms (KPMG, PwC, McKinsey), health, and education involving telemedicine and e-learning. Another major initiative to deal with unpredictable job requirements is to resort to multiskilling, which is very common in software companies like TCS and Infosys.

Manufacturing/Supply Chain Flexibility

Manufacturing and supply chain flexibility initiatives are widely used to cater to the variability and uncertainty of demand. Some important types of flexibility are volume flexibility, routing flexibility, tooling flexibility, material handling flexibility, and so on. An important flexibility initiative taken by manufacturing companies like auto manufacturers (Maruti Suzuki, Tata Motors, Toyota, etc.) is in the form of variable capacity. Another good initiative taken on the supply chain front is by bottlers of beverages like Pepsi for tracking the movement of bottles so as to pin point the source of any deficiency spotted at the point of purchase.

Information Systems Flexibility

Flexibility in information systems is provided in terms of modularity, scalability, mobility, and so on. The integrated systems like ERP follow a modular design. The service industries information systems utilize mobile applications for anytime/anywhere use.

1.2.2 Case Illustrations

Some case illustrations from real-life flexibility initiatives are outlined in this section.

Hero Group

It first entered in a joint venture (JV) with Honda to manufacture bikes in India, which recently got expired, after which it established Hero MotoCorp. It has been regularly introducing new product lines to capture different customer segments and has been able to effectively cope with the changed situation.

Maruti Suzuki

Maruti Suzuki, which started as a JV of Suzuki Corporation and Government of India, is now a subsidiary of Suzuki in India. It has been taking various flexibility initiatives over time. Starting from a small car manufacturer, it has been introducing product variants to suit the requirements of different customer segments. It has also

been upgrading its individual models in a segment to meet changing needs of the customer. It started as an "economy" brand with the concept of a common man's car, which has been extended to "economy with style" with its new models like Dzire.

Tata Motors

Tata Motors has traditionally been a manufacturer of commercial vehicles. Keeping in view the growth in passenger cars demand, it diversified into the passenger vehicles segment with the first indigenously developed car model "Indica". It approached various collaborators and took the design help from Italy and engine technology from France. It then entered to the lowest level segment with "Nano" and also went to higher segment by acquiring "Jaguar" to induct new technology. These strategic initiatives have resulted into exponential growth in its turnover.

Honda

Honda has taken flexibility initiatives globally as well as in India. An early example of introducing flexibility in manufacturing is when Honda was introducing Civic 2001 in the trio of the developed world, i.e., USA, Europe, and Japan. For this, it was supposed to use the same assembly lines that were used for other models. It used robots to replace jigs and fixtures, so that these could be retrained rather than going for retooling, which reduced the set up time from 7 days to overnight.

In the Indian context, which is a price sensitive market, it used marketing and strategic flexibility initiatives to regain the eroding market share at two different stages. At one time, it used dynamic pricing to substantially cut the price of its all models to match with the competitors and quickly regained market share. At another stage, when the fuel prices were going high, all the major manufactures in India introduced diesel versions except Honda. This resulted to reduce it to a lower competitive ranking in sedan segment. It strategically worked with new management team to come up with diesel version which again put it back on the pedestal. In today's context, the situation has further changed due to declining fuel prices and restrictions on diesel vehicles in view of pollution.

Cisco

Cisco moved to agile product development in order to meet the dynamically changing needs of its customers. It gave up the traditional fashion of project bound teams and moved to collaboration by way of self-organizing and cross-functional teams.

McDonald

McDonald has taken a number of flexibility initiatives to enter new markets and beat the fast-food competitors. It has exhibited sensitivity to local taste and preferences and affordability to suit Indian customers' pockets. It promoted family dining experience and innovative practices such as first to start home delivery in India.

Unilever

Unilever replicated the flexibility initiatives in the developed world that were originated in its Indian operations. HUL (its Indian subsidiary) launched a sachet blitz across power brands for product penetration at the bottom of the pyramid in an effective manner.

E-commerce Companies

The e-commerce retail companies like Flipkart have taken a series of flexibility initiatives to overcome the hesitation of Indian customers (to accept e-buying) such as extended return period, extended support hours, cash payment on delivery, and try out sizes of apparel at home before you buy. This has given these e-retail companies a space out of the traditional brick and mortar retail market.

1.3 Flexibility Valuation: The Basic Model

The valuation of flexibility at generic level has been lacking. Sporadic works in isolated areas are available such as effect of decision flexibility on value of information (Merkhofer 1977); valuing financial flexibility in volatile markets (Mason 1984); valuation of flexible production systems using contingent claims pricing (Triantis and Hodder 1990); value of flexibility in project selection (Kulatilaka 1993); valuation of operating flexibility (in terms of breadth) of multinational corporations (Allen and Pantzalis 1996); value of information system flexibility in terms of modification/upgradation following its initial implementation (Schober and Gebauer 2009); valuation of flexibility in international investments during economic crisis (Lee and Makhija 2009); and so on. In most of the cases, the most common approach was to carry out valuation of real options.

The flexibility valuation model, proposed in this chapter, is based on the fulfillment of needs driving flexibility and the capabilities required to fulfill the same (Sushil 2015c). In any aspect of business, flexibility is required due to uncertainty, variability, provision of choice, and requirement of speed in response or delivery mechanisms. To meet these requirements, capabilities are to be developed on the fronts of people, process, technology, supply chain, and the ecosystem. Some of the strategic goals to be achieved by flexibility initiatives in any organization and the related cost factors are portrayed in Fig. 1.1.

By meeting the needs of the organization, the benefits derived by flexibility initiatives in general are as follows:

- Capturing new opportunities
- Generating new ideas and innovation
- Opening new revenue sources

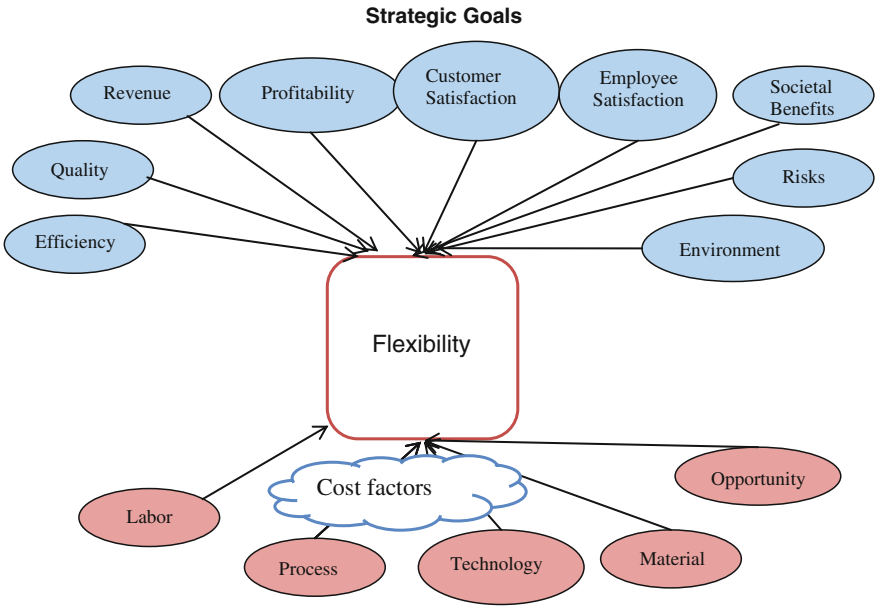

Fig. 1.1 Strategic goals and cost factors

- Hedging risks
- Reducing process cost and time (Minimizing waste)
- Anytime/Anywhere Reach
- Stakeholder involvement and Societal benefits—Inclusion

Some specific benefits linked with typical flexibility initiatives are shown in Table 1.1.

But while realizing these benefits there are both tangible and intangible costs for implementing flexibility initiatives in different areas as outlined below:

Tangible cost factors

- More options-increased costs of process and product design
- Training costs
- New technology costs

Table 1.1 Specific benefits of flexibility initiatives

Flexibility initiatives	Benefits
Customization	Improving quality
Dynamic pricing	Extracting value
Flexible capacity	Low inventory and meeting unforeseen requirements
Multiskilling	Low manpower costs and meeting unforeseen job requirements
Flexible work	Employee satisfaction

- Cost of restructuring
- Change management costs
- More initial costs-less running costs
- Cost of working capital

Intangible cost factors

- Difficulty of practicing
- Cognitive overload
- System complexities and chaos

For enhancing the value of flexibility the benefits are to be enhanced and costs are to be curtailed. The definition of value or affordability of a flexibility initiative is a ratio of the worth of the initiative to the organization in terms of benefits derived to the cost incurred for the same as given below

$$\text{Value (Affordability)} = \text{Worth}/\text{Cost}$$

The basic model of valuation of flexibility is depicted in Fig. 1.2. Any flexibility initiative is intended to fulfill certain needs for flexibility which will result in generation of certain benefits to the organization as well as stakeholders, which may be tangible as well as intangible in nature. On the other hand, for the effective implementation of that initiative the organization will require to develop certain capabilities. The capability building would entail both tangible and intangible costs. The ratio of benefits to costs would give valuation of the flexibility initiative to assess its affordability by the organizations.

The valuation of any flexibility initiative is contingent on the context, i.e., type of industry, maturity of processes, and maturity of actors. If an industry is facing high turbulence such as telecom, the flexibility is likely to get high valuation in contrast to comparatively stable industries such as fertilizers and chemicals. The

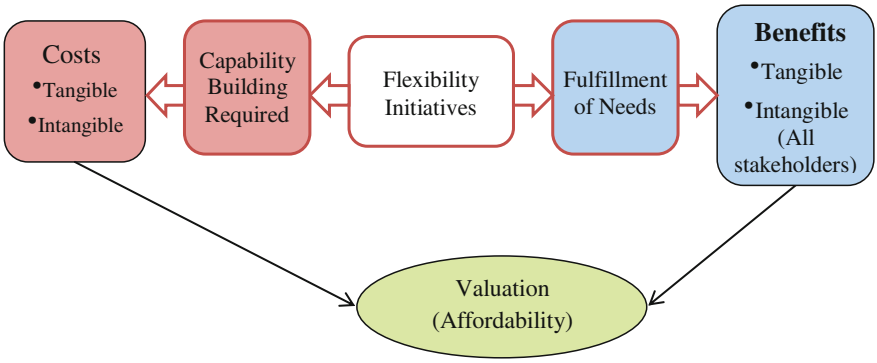

Fig. 1.2 The basic model of flexibility valuation

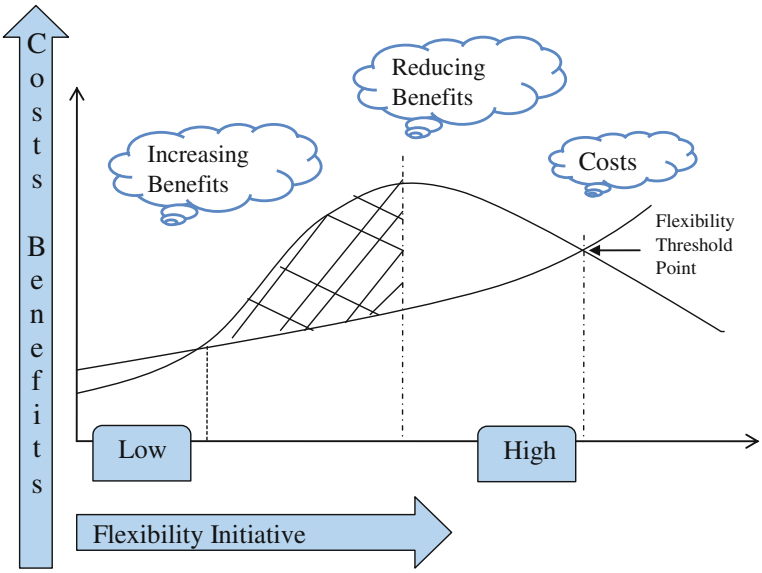

Fig. 1.3 Optimize benefits with costs

maturity of processes as well as actors would generate higher benefits than costs incurred. As shown in Fig. 1.3, in the beginning for any flexibility initiative the benefits would be low which would increase with an increasing rate with the maturity, but the rate of growth of costs would be lower than the benefits, which would make it more viable after some time.

The valuation also depends upon the perspective from which it is carried, i.e., organizational perspective or stakeholder perspective. The stakeholder perspective would be different for different stakeholders such as employees and customers. A particular flexibility initiative might not be of that high value to the organization but would be of great value to employees, e.g., flexi-time/flexi-place work practice. In some cases, it may be of high value to both the organizations and the stakeholders. In this chapter, the valuation is primarily done from the view point of the organizations.

The flexibility in systems could be both flexibility to use and flexibility to change. The flexibility to use is linked with current requirements in terms of options and freedom of choice, whereas flexibility to change is related with anticipated as well as unanticipated future requirements. The high technology systems with short life cycle would normally have higher value for flexibility to use than to change. In case of long life systems, such as buildings, flexibility to change may also be of high value.

1.4 Examples of Flexibility Valuation

In this chapter, the valuation of following three flexibility initiatives is depicted using the basic model given in Fig. 1.2.

- Variable capacity
- Multiskilling
- Flexi-time/flexi-place

The basic model is applied in all the above three cases and illustrative models are shown in Figs. 1.4, 1.5 and 1.6 respectively.

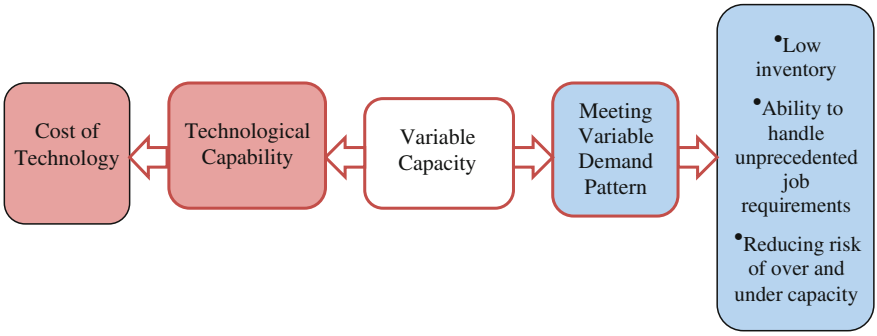

Fig. 1.4 Valuation of flexibility initiative 1

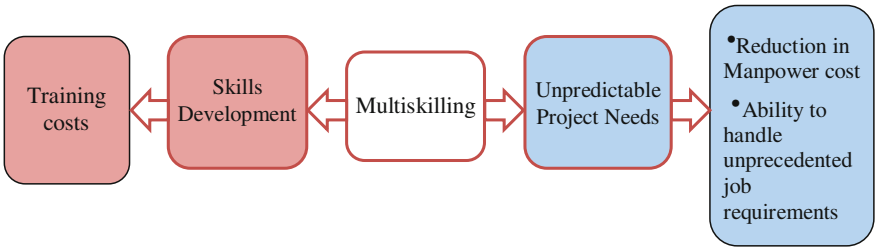

Fig. 1.5 Valuation of flexibility initiative 2

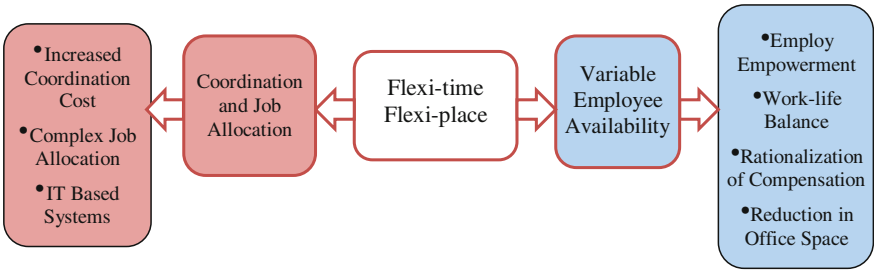

Fig. 1.6 Valuation of flexibility initiative 3

1.5 Different Valuation Plans

The valuation of flexibility could be done in multiple ways. Some of the possible valuation plans are outlined in this section, out of which one is illustrated in the next section.

(i) *Go–No-Go Flexibility Initiative*

The valuation would give either to adopt the flexibility initiative (affordability index greater than 1) or not to adopt it at this juncture (affordability index less than 1). In case of affordability index equal to one, the decision could be either way depending upon other considerations, such as future requirements, cruciality of area, and so on.

(ii) *Assessing Extent of Flexibility*

Initially, with introduction of some flexibility the affordability would be low. As the flexibility index is enhanced the affordability is also expected to grow, but after an extent of flexibility it might mature and this may start tapering down, as shown in an expected relationship in Fig. 1.7. This needs to be validated in individual cases and the valuation plan would be to assess the extent of flexibility to be introduced in that area.

(iii) *Time-Based Valuation*

As initially the costs of capacity building would be high and the benefits will accrue over time, the affordability index of a flexibility initiative might take a S-shaped pattern as shown in Fig. 1.8. Thus, the valuation plan would be to assess the time at which a particular initiative would become affordable and start giving positive value.

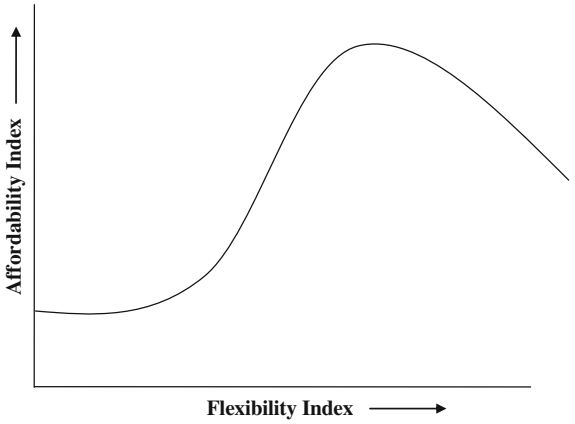

Fig. 1.7 Flexibility versus affordability

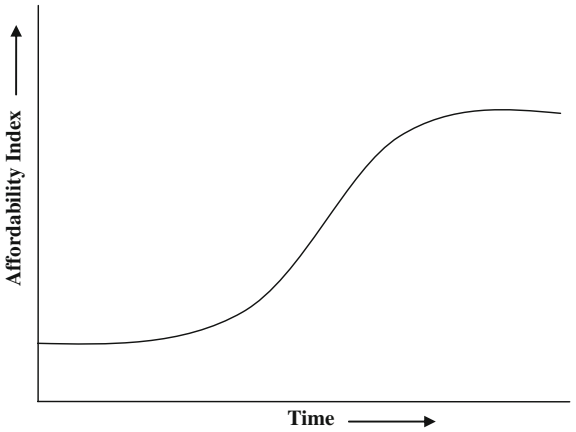

Fig. 1.8 Time versus affordability

(iv) *Valuation at Different Flexibility Maturity Levels*

The flexibility maturity model has six levels (Sushil 2012c, 2016a), i.e., (1) flexibility in individual processes; (2) flexibility in interaction of processes; (3) flexibility in actors; (4) strategic flexibility; (5) operational flexibility in value network; and (6) strategic flexibility across the ecosystem. It is envisaged that the value of flexibility would get enhanced with higher maturity levels as depicted in Fig. 1.9.

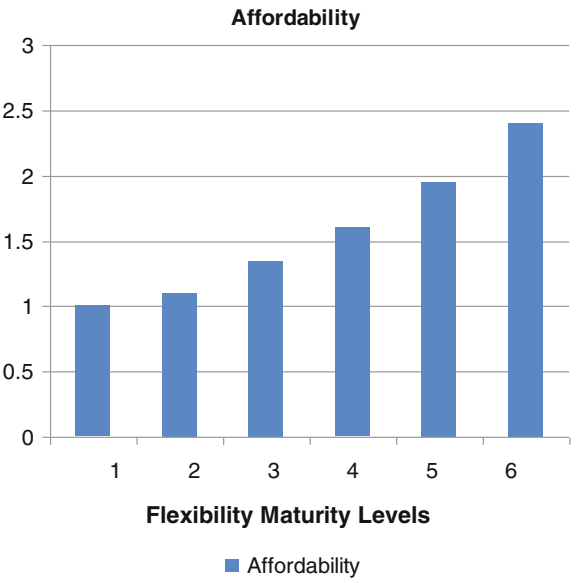

Fig. 1.9 Valuation at flexibility maturity levels

(v) *Flexibility Assessment on Value Chain*

The value of flexibility at different stages of direct as well as indirect value chain is expected to be different. It would be worthwhile to assess that flexibility at which stage in the value chain would provide maximum value.

(vi) *Comparative Evaluation of Different Flexibility Initiatives*

A multi-criteria ranking of different flexibility initiatives under consideration can be done to decide about which ones should be adopted on a priority basis. An illustration on the same is provided in the next section.

1.6 Multi-criteria Ranking of Flexibility Initiatives

The three flexibility initiatives outlined in section four are ranked using a combination of Interpretive Ranking Process (IRP) (Sushil 2009) and Total Interpretive Structural Modelling (TISM) (Sushil 2012d, 2016c). TISM is applied to develop hierarchical relationships of the criteria used for ranking, i.e., benefits and costs. This is further used to derive weightages of the criteria to be used in IRP based on their respective driving power. IRP is used to rank the flexibility initiatives with reference to the benefits and costs as multiple criteria for evaluation. The cost criteria is taken in a negative manner, i.e. lower cost means more dominance for a flexibility initiative.

The flexibility initiatives used in Sect. 1.4 and the select criteria (benefits and costs) are summarized with codes (from the models given in Figs. 1.4, 1.5 and 1.6) in Table 1.2.

Table 1.2 Flexibility initiatives and select criteria for valuation

Code	Flexibility initiatives/Criteria
Flexibility initiatives	
F1	Variable capacity
F2	Multiskilling
F3	Flexi-time/Flexi-place
Benefits	
B1	Low inventory
B2	Ability to handle unprecedented job requirements
B3	Reduction in manpower cost
B4	Work–life balance
Costs	
C1	Training cost
C2	Coordination cost
C3	Cost of technology
C4	Complex job allocation

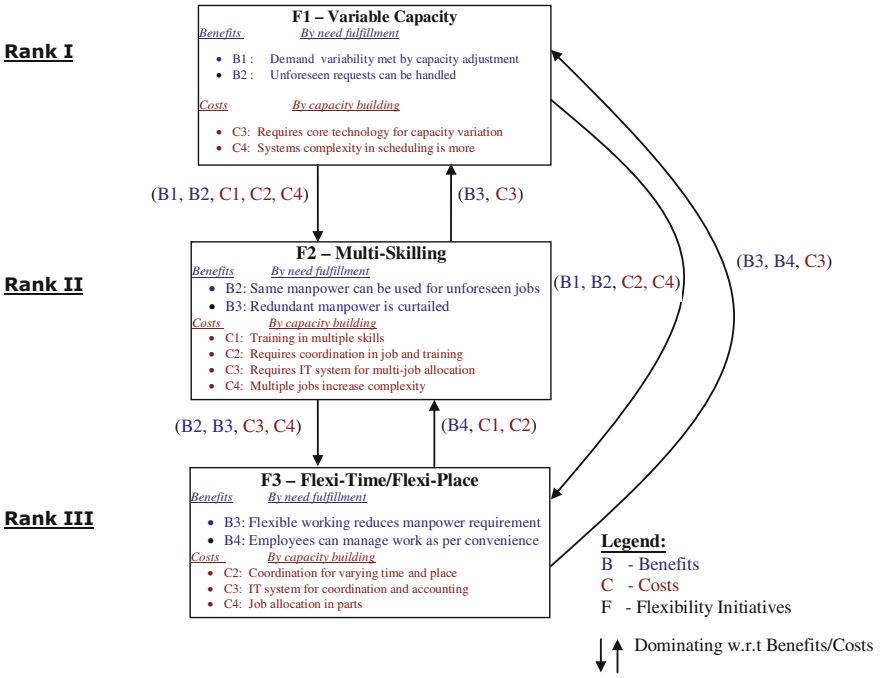

Fig. 1.10 IRP model of ranking of flexibility initiatives (*Source* Sushil 2017)

After implementing the TISM-IRP process the ranking of flexibility initiatives has been obtained as shown in Fig. 1.10 (Sushil 2017). The application illustrated here at a generic level and not with reference to a specific case organization.

1.7 Conclusion

This chapter has provided a conceptual framework of flexibility valuation. A basic model is provided, which has been illustrated in case of three flexibility initiatives. These three initiatives have also been ranked using TISM-IRP process with respect to the benefits and costs. An outline of other valuation plans is also provided. It requires to validate the proposed basic model in real life cases with empirical evidences. In future, specific models of valuation can be developed in different flexibility areas. The models with the perspectives of different stakeholders may also be explored.

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Chapter 2
The Flexibility in Product Family Engineering Process

Sanjai Kumar Shukla

2.1 Introduction

The easy exploitation of product's features and adaptability leads to mass acceptance among user community. The abrupt behavior of products is detrimental to product usage and acceptance. The organizations properly anticipate the usage pattern and accordingly devise stable and quality products which come as customer delight. The feedback from advance users is a great help in entire cycle of product development. The PFE process is result of continuous product improvements with time, cost implications, and change management. The substantial changes originated from user groups for improvement leads to a new product in a family. The quantum improvements, desired characteristics, and short life cycle of product are identified as contributing factors for its usage (Agrawal and Haleem 2005). Some organizations provide free licenses of products to potential users to get the valuable feedback and accommodate these feedbacks by constant innovation. The number of product families existing in the organization is used as an indicator of PFE flexibility in this study. The product families supplement the core product line by introduction of related set of products which helps the exploitation of main products by customers. The PFE leverage on customer's loyalty who are inclined to choose related products from same organization rather than evaluating products from different organizations.

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2.2 Background Theory and Literature Review

The literature review focuses on finding relationship among resources and capabilities to exploit them for new product development using PFE. The candidate to represent the PFE flexibility is explored in the existing literature. The flexibility can be visualized at core of all processes of organization and strategic flexibility has overall impact on firm performance (Abbott and Banerji 2003; Jha 2008). Beamon (1999) utilized output volumes and number of different product types in defining delivery flexibility in supply chain. In the context of flexibility in PFE, the number of product types is parallel with the number of products in product family. Nadkarni and Narayanan (2007) utilized the firm performance as dependent variable of fit between speed of industry change and strategic schema. The product perspective in the strategic schema has close resemblance with strategic intention in decision process. The innovativeness by employees results in niche specification of products through organizational flexibility. Sánchez et al. (2011) reported positive relationship between innovativeness and flexible human resource practices. The technology management, strategic flexibility, and human resources are important enablers for shaping core competence (Kak and Sushil 2002). Verdu et al. (2009) noted positive correlation between intention and responsiveness which represents the main aspect of flexibility to respond to change. The flexibility elements are greatly influenced by human resource (Kara et al. 2002). Zhou and Wu (2010) suggested that greater technological capability is associated with explorative innovation which is necessary for PFE. Stephenson and McDermid (2005) emphasized on deriving the flexibility requirements from customer's uncertainty which may help specification development of products. The product's scope and phases of lifecycle are driven by the organization's own resources and external support system. The multiple configuration baselines of products help to consolidate similar products under umbrella of PFE.

2.2.1 New Product Development and Product Family Engineering

New product development requires research and development along with innovation in market; the PFE offers the advantage for both aspects. The existing infrastructure and technology in the organizations are utilized for developing new products under PFE and the existing customer base can be utilized for commercialization. The customer's loyalty can be exploited for relatively easier introduction of different set of products. The associated risk in PFE is low due to above reason. The existing customers may facilitate with advance ideas regarding product specifications. The ease of integration of products from same organization can be offered as additional benefits to user community. The organization starts with core product offering, and later on builds the product family for allied needs of customer

through product diversification. The matured products resulting from PFE become part of product portfolio with time and another set of new products comes under PFE through further innovation and strategic intention for holistic customer serving through a variety of products. The product families have good chance of survival as compared to new product introduction in market. The intermediate products, exploratory, and exploitative innovations are helpful in strategic renewal process (Balasubrahmanyam et al. 2012). The resource requirement for PFE can be estimated with relative ease and releases of products can be planned accordingly. The asset per employee can be visualized as part of overall capability of organization to accomplish contingent activities and PFE. The method of diversification of products into various product families can be elucidated from two scenarios. In first case, organization develops core products; later on it offers the related products and finally turns into dominant player in this new segment. In second case, the organization serves the core product of another organization and further develops capability to produce competing products. This can be explained in case of M/s Google entering into internet surfing and acquiring capability to develop operating systems at later point of time. In both cases, the organizations utilizes the PFE to serve customer needs. The new product development is a valued strategy to achieve the competitive advantage and lack of flexibility in the processes can penalize the organizations (Singh and Sushil 2004). The PFE can emerge from multiple reasons some are, (i) similar set of product with varying degree of specifications, (ii) offshoots of core product marketed separately, (iii) products introduced to fully exploit the core products, and (iv) products to encash integration requirement from market. In many cases the organizations offering core product does not want to expose the interface of product, so that customer is forced to buy the products from product family to meet the integration requirements.

Incremental growth in product families is observed for IT organizations where product versions with specific features are evolved over period of time due to preplanned activity, result of user feedbacks and dissatisfaction with current product's performance. The valuable feedback is obtained in concept proving, existing and new market testing, development, prelaunch and postlaunch phases. In the preplanned activities, the allocations of resources for certain products are done and next set of resources are planned for future upgrade. The product families complementing or competing with other organization products results in new set of products through PFE. The product family needs to have stability w.r.t. to different computing environment and usage platforms for mass acceptance. The output of PFE is several products in production lines of IT companies. There may be some degree of variability among architecture of different product family members. The flexibility valuation framework (Sushil 2015a) favors the product development using PFE over entirely new product development. This is because cost of existing infrastructure, existing architecture exploitation, and experiential learning is less than creating these things for new product development.

2.2.2 Strategic Intent and Product Family Engineering

The strategic intent to serve related business around core products of an organization results in more products due to holistic serving of customers' needs in long term. The strategic intent is a logical consequence of visionary and thoughtful leadership which benefits the organization by consolidation of current product profile and alignment of resources on sustainable basis. Vecchiato (2015) indicated that planning and learning are important for strategic decision-making by studying influential organizations in the year 2000. Hu et al. (2013) reported the importance of new and flexible product strategies for wealth and value creation in markets. Many global organizations create wealth through PFE in implicit terms and try to control over business environment through strategic intent. The lower cost can always be emphasized as incentive for products through PFE. For the MNCs the global leadership and talent are productively utilized for innovation under PFE to address potent demand. In particular, focus on relationship building and communitarian approach helps in global project execution (Christina 2013). In many cases, this results in product specifications so well elaborated that most advance users cannot anticipate it. PFE is a good example of managing continuity and change together (Sushil 2013) in technological area, where product's common architecture is extended to retain current market and explore new markets by addition of new architectural capabilities in the product design. The continuity and change both are emphasized in all the approaches including new product development as organizational endeavors in postmodern approach (Sushil 2014).

2.2.3 Resource-Based View of Product Family Engineering

The identification of resources with potential for deployment in the PFE process needs to be done along with reshuffling of resources of core products development as both the activities goes hand in hand. The tangible resources deployed in successful developmental process result in more resources due to profit of firm in business cycles on continuous basis giving more interrelated product families. Vanacker et al. (2011) examined the relationship between financial bootstrapping and venture growth. It was concluded that ventures deploying their funds, personnel and additionally leveraging the subsidy show significant growth. The resources positively enhance capability which further drives the useful innovation. The financial resource has greater impact on enhancing firm's capacity to support desired innovations in the organization (Lee et al. 2001).

2.3 Theory Development and Literature

There is dearth of published literature dealing with indicators of flexibility in PFE. In the IT organizations, the number of products in related family can be taken as indicator of flexibility in the absence of any available indicator. This flexibility is representative of life cycle, resource exploitation, and strategic intent resulting in PFE in organization. The resources are identified in terms of infrastructure, manpower along with their skill level, cash flow, accumulated reserves, and retained earnings to handle PFE process. However, the quality of resource is ignored in current study and assumed to be uniform for all the organizations. This chapter finds impact of these resources on PFE including specialized effort indicated by human resource deployment, R&D spending, total asset, and retained earnings which are readily deployable asset. The assets are also normalized on per employee basis for easier comparison across organizations. Irrespective of use in PFE, these resources can be utilized for unforeseen circumstances enabling organizational flexibility for responding to uncertainty. The continuous products upgrade indicates the existence of innovations in product. The data about assets and employees are taken from audited data, i.e., balance sheet and organizations websites.

2.3.1 Hypothesis for Analyzing the Factors Impacting PFE Flexibility

Hypothesis 1: There is positive impact of total asset of organization on flexibility in PFE indicated by number of product families.

The organizational assets are composed of two parts; first is committed and second is flexible resource. The flexible resource is exploited as per need and committed resource is exploited as per obligation of long- and medium-term plans. For the human resource both categories applies which can be redeployed for PFE. In this chapter, the relationship between assets (indicated from balance sheet), and number of product families is investigated for leading IT product organizations. For the sustained business the new product families and core products together are required for PFE. The scanning of external environment primarily drives new product development.

Hypothesis 2: There is positive relationship between focussed organizational effort indicated by R&D spending and PFE flexibility indicated by number of products in family.

The R&D expenditure for driving PFE can be attributed to long-term commitment and strategic intent. The IT sector is technology intensive and the organization's performance is dependent on R&D output. The choice of technology

facilitates this process as part of R&D strategy. This strategy places important guidance for selection of products for PFE considering the external and internal perceptions for organizational alignment of resources. The enhancement of core competence is required for PFE instead of creating new competence.

Hypothesis 3: There is positive relationship between immediate deployable resources indicated by retained earnings and PFE flexibility.

The availability of ample assets helps in mitigating the risk in experimentation and enhances the capabilities for investment in PFE. The cash, current assets, and human resources can be immediately deployed; these have potential to induce flexibility in organization to manage external threats. The retained earnings can also be strategically put for PFE along with commonly envisaged use as safety net. Papanastasopoulos et al. (2010) also noted that all types of retained earnings, i.e., current operating accruals, non-current operating accruals, and retained cash flows impact the future profitability. The investigation of relationship of retained earnings with PFE flexibility is done in this research work.

Hypothesis 4: There is positive relationship between employee innovativeness and PFE flexibility.

Employee innovativeness is reflected by innovative behavior and outcomes. It starts with product's conceptualization, development and finally to commercialization. The innovations and creativity are required at organizational, departmental, and individual levels. The strong commitment in new and innovative work mandates the individual to be experienced, self-creative, technically suitable, motivated with strong cognitive capabilities. The organizational restructuring for proper job specification, R&D and management commitment supports the innovations. The work–life balance also positively influences the innovativeness which transforms to success in PFE process. The strategic goal for Japanese companies is employee's development, and in European countries it is cost optimization (Hamel and Prahalad 2005). In innovative organizations like Texas instrument, the employees find new businesses in the white spaces which strongly help the PFE. In the leading organizations, the number of employees is taken as indicator to represent the scale of innovativeness.

Hypothesis 5: There is positive relationship between organizational asset on per employee basis and PFE flexibility.

These are long-term assets normalized at per employee basis for easier comparison among organizations and indicates composite of the asset availability, scale of PFE, and profitability.

2.3.2 Sampling and Analysis of Data

The global IT organizations are taken in this analysis. In these organizations, the PFE has matured and culminated into several products. The items under analysis are taken from audited reports of these organizations. The financial statements are being prepared on actual basis and audited by external auditors, thus internal and external validity of data items utilized from these financial statements are ensured. The current and previous year's data from balance sheet is utilized for analysis. The assets and profits are available in balance sheet and numbers of employees working in these organizations are taken from Wikipedia and organizational websites whichever is latest and available.

The hypotheses are validated by comparing information of variables (manpower resources, asset per employee, total assets, and retained earnings) and number of product families in separate analysis. The product portfolio and product families have been stabilized over period of time and influencing the performance in case organizations. The regression is done to establish the relationship between these variables. Pearson's correlation is used to explain the results which are presented in last section of this chapter.

2.4 Application of TISM for Leading Factors in IT Organization

The TISM (Sushil 2012, 2016) is utilized to identify various levels of factors chosen for hypothesis testing for analyzing flexibility in PFE. The factors are R&D spending (F1), total asset (F2), number of human resource (F3), retained earnings (F4), and normalized asset available on per employee (F5). All these factors are identified from literature survey along with contextual relationship between them which also include direction of influence of one factor over another and validated by experts. The reachability matrix, antecedent set, and intersection sets are prepared accordingly to identify all the levels in TISM.

2.4.1 Contextual Relationship for TISM

The relationship among factors are analyzed in context of global IT organizations because of the stabilized pattern of asset deployment for PFE over long periods. The R&D expenditure from annual reports is assumed to be utilised uniformly across organizations for innovations. For these organizations technological outcome is basis of overall performance which has strong linkage with PFE as well. The R&D performance results in asset creation, niche products, trademarks, patents and the relationships in reachability matrix are marked accordingly. The R&D performance

results in cash flow; if the return of R&D is not substantial then also the organization with high R&D are valued higher in market (Chan et al. 2001). Galan and Sanchez (2006) noted that R&D intensity positively impact product diversification which may initiate PFE. The retained earnings augment the R&D spending. The relationships in the reachability matrix focus on achieving desirable state with reference to characteristics of PFE.

Following relationships are explained with reason of direction of influence of first factor over second. The less significant relationships are not mentioned here and consequently they are not reflected in reachability matrix.

F1–F2: Introducing niche products which results to increased organizational asset.
F2–F1: Ample assets cause more investments in R&D and innovations.
F1–F3: Investments for skill development.
F1–F5: Strategic initiatives to maximize performance and productivity.
F5–F1: Decides capacity of organization to spend for innovation.
F2–F3: Investment in human resource at global scale for expansion purpose.
F2–F5: Investments for mainly consolidation purposes.
F5–F2: Acts as lever for deciding the optimal spending of resources.
F4–F1: Strategic decision to invest in the R&D in substantial scale for long-term returns.
F4–F2: Organizational products generating profits and wealth by multiplier effect.
F4–F3: Getting skilled manpower from external sources.
F4–F5: Developing the internal resources for maximum benefits and productivity.
F5–F3: Acts as lever for deciding the optimal manpower.

The above discussion is summarized below for application of TISM in Table 2.1.

The reachability matrix showing relationship among variables is given in Table 2.1.

Operation of steps of TISM is depicted in Table 2.2 in three iterations.

Table 2.1 Reachability matrix

Factor	R&D spending (F1)	Total asset (F2)	Number of employees (F3)	Retained earnings (F4)	Total asset per employee (F5)
R&D spending (F1)	1	1	1[a]	0	1[a]
Total asset (F2)	1	1	1	0	1
Number of employees (F3)	0	0	1	0	0
Retained earnings (F4)	1	1	1[a]	1	1[a]
Total asset per employee (F5)	1[a]	1	1	0	1

The 1[a] indicates the transitive relationship

Table 2.2 TISM steps

Factor	Reachability set (RS)	Antecedent set (AS)	Intersection set	Level
Iteration-1				
R&D spending (F1)	1, 2, 3, 5	1, 2, 4, 5	1, 2, 5	
Total asset (F2)	1, 2, 3, 5	1, 2, 4, 5	1, 2, 5	
Number of employees (F3)	3	1, 2, 3, 4, 5	3	I
Retained earnings F(4)	1, 2, 3, 4, 5	4	4	
Total asset per employee (F5)	1, 2, 3, 5	1, 2, 4, 5	1, 2, 5	
Iteration-2				
R&D spending (F1)	1, 2, 5	1, 2, 4, 5	1, 2, 5	II
Total asset (F2)	1, 2, 5	1, 2, 4, 5	1, 2, 5	II
Retained earnings F(4)	1, 2, 4, 5	4	4	
Total asset per employee (F5)	1, 2, 5	1, 2, 4, 5	1, 2, 5	II
Iteration-3				
Retained earnings F(4)	4	4	4	III

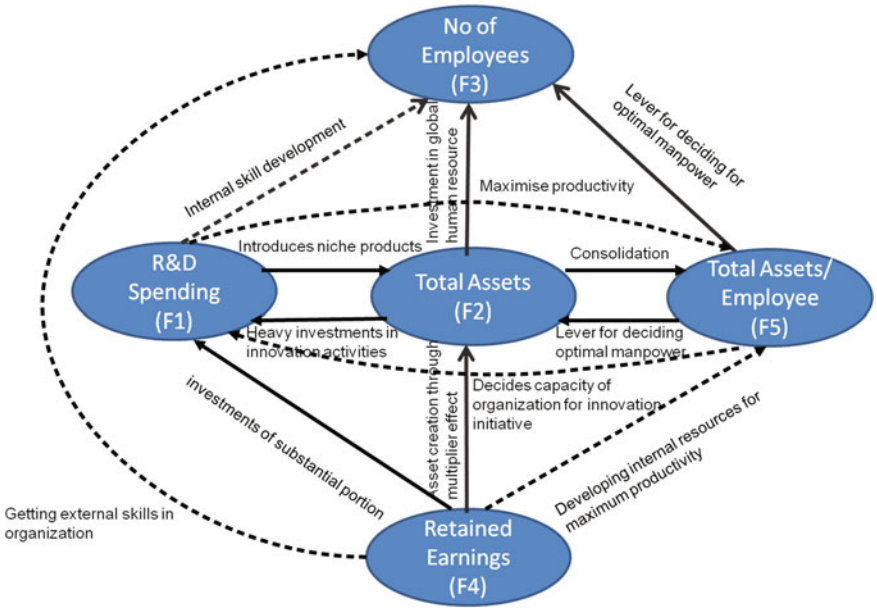

Fig. 2.1 TISM levels

2.4.2 Representation of TISM Results

The findings are visually presented in Fig. 2.1 and critically analyzed in last section of this chapter.

2.5 Conclusion

The increase of assets with increased products in product family shows the intention to serve customer in that segment successfully and holistically. However, the analysis of all five hypotheses shows low correlation between asset and number of product family. It is observed that number of employees has greater influence on number of product families which can be inferred from the fact that in IT companies the innovation is primarily driven by skilled and committed human resources. The correlations with number of products and other factors are not significant and there is weak relationship with retained earnings. The results of TISM strengthens the commonly observed and generic behavior of IT organizations. The retained earning has emerged as most important asset from this analysis. The factors in order of importance are number of employees, R&D spending, and total asset with their effective use for PFE. The strategic intent for PFE is reflected in using of retained earnings for this purpose.

In this study, important guideline for PFE has emerged. The organizations need to focus on employees and increase their numbers to strengthen PFE. The retained earnings are other important resources useful for PFE which can create multiplier effect on enhancing human resource and asset creation. The synthesis of results of hypothesis testing and TISM points to use of the retained earnings in human resource development and enhancement for driving successful PFE. The flexibility in PFE can be enhanced proactively by institutionalizing suitable changes in organization (Sushil 2015b). The quality of asset, manpower, and other resources are assumed to be uniform across all the organizations which can be differentiated in future studies.

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Chapter 3
Total Interpretive Structural Modelling of Innovation Measurement for Indian Universities and Higher Academic Technical Institutions

Akriti Jain, Ruchi Sharma and P. Vigneswara Ilavarasan

3.1 Introduction

Innovation is the key driver that fuels technical progress and facilitates long-term economic growth (Maclaurin 1950; Solow 1956; Denison 1962; Jorgenson and Wilcoxen 1990; Rosenberg 2004). Innovation in the economy is conducted through Research and Development (R&D) activities either by private players like industrial labs or by public bodies like publically funded research organizations, universities and academic institutions. All these actors together form the innovation system of the country.

Realizing the role of universities and higher academic institutions in national innovation system, governments all over the world take policy initiatives to encourage innovation and information flows through these institutions (Nelson 1986). While chunk of resources are being allocated to these institutions, there is a need to look at the efficiency with which these resources are being utilized to create innovative output. Existing literature like Fritsch and Slavtchev (2007), Langford et al. (2006) measure innovation largely through patents. Against this, some literature like Nelson and Winter (2009), Caraça et al. (2009) argue that all inventions by universities are not patentable, moreover, not all patentable inventions are actually patented. Thus, there is a need to have a comprehensive conceptual

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framework that should not only allow empirical measurement of overall innovation performance; but should also indicate efficient utilization of the resources allocated to different departments of these institutes. In effect, it should provide guidance to the policy-makers regarding the further allocation of resources based upon the past performance and future expectations.

Measurement of innovation has always been an important source of concern for researchers and policy-makers. Earlier attempts of innovation measurement (Ames 1961; Blackman et al. 1973; Pavitt 1982; Acs et al. 2002; Langford et al. 2006; Jalles 2010; Schwartz et al. 2012) were focussed entirely on the data of R&D expenditure and patents which could act as innovation proxies. However, subsequent developments in the field of innovation measurement study (Abernathy and Clark 1985; Oslo Manuel 2005; Nelson and Winter 2009; Arundel and Huber 2013; Cruz-Cázares et al. 2013; Hoarau and Kline 2014) shifted focus towards more holistic approach of innovation measurement which is called the "systems approach" of innovation. This approach takes into account the role and implications of each and every element that are weaved together to form various sub-processes, acting in an integrated manner to build the overall innovation process. It is very crucial to understand the role of every element and actor in building the innovation systems. There has been scant literature on innovation measurement from systems perspective (Guan and Chen 2010).

This chapter attempts to bridge this gap by developing a comprehensive conceptual framework and structural model for the measurement of innovation by universities and higher academic technical institutions. More specifically, the chapter focuses on the question: how to develop and interpret a structural model that can be used as a guide to measure innovation by universities and higher academic technical institutions? This is done, first, through developing a theoretical framework showing various elements or indicators of innovation by higher academic technical institutions and then identifying a structural model depicting the inter-relationship between them. We identify various indicators based on a theoretical framework using classical and contemporary literature on innovation. Further, Interpretive Structural Modelling (ISM) technique has been used to build the structural model depicting the relationship among those indicators. Links and nodes of the structural model thus developed is then strengthened and interpreted through the methodology of Total Interpretive Structural Modelling (TISM). Structural model thus build is then subjected to the indicators' classification to understand the relative dominance and strength of indicators through the technique called MICMAC analysis.

In the remainder of the chapter, we first build the theoretical background for innovation measurement in Sect. 3.2. We, then elaborate the research methodology that has been used to build the structural model along with the justification for the methodology used in Sect. 3.3. Subsequently, we present our analysis in Sect. 3.4 and then in Sect. 3.5 we conclude with the implications.

3.2 Theoretical Background

A substantial work was done during 1950–60s to conceptualize the term 'innovation'. Joseph Schumpeter who is considered to be one of the most original social scientist of the twentieth century did the revolutionary work in studying the role of innovation in economic and social change. His idea of innovation is not limited to the introduction of new and commercially applicable product or process but it involves myriad of aspects like exploitation of new market, development of new sources of supply and new ways to organize business (Schumpeter 1934). Earlier definitions of innovation given by Oslo Manual of OECD were specifically focussed upon technological product and process innovation. Subsequently, large scale surveys like European Community Innovation survey (ECIS) brought refinement in the concept and expanded its coverage to non-technological innovation. Ames (1961) earmarked demarcation among terms like research, invention, development and innovation and emphasized on economic transaction of new articles, technologies or processes in order to be qualified as innovation. In this study, adopting the definitions of Hurley and Hult (1998) and Santacreu (2015), we define innovation as the development of prototype of any good (or new idea), selling or transferring it to industry/government/small businesses or other stakeholders to convert it into intermediate or final goods to reap benefits out of it.

In order to measure innovation, researchers developed various frameworks depicting the process of innovation through different models. These models are linear model (Bush 1945; Brozen 1951; Ames 1961; Libik 1969); coupling model (Utterback 1971; Rothwell 1994; Kline and Rosenberg 1986); chain-linked model (Kline 1985; Kline and Rosenberg 1986), triple-helix model (Leydesdorff 2012) and multi-channel interactive learning model (Caraça et al. 2009) with theoretical underpinning from different economic theories. Linear and coupling models of innovation formed their foundation from the theory of technical change (Maclaurin 1950; Schmookler 1954) which is in harmony with the classical and neo-classical economics. Serious criticism to these theories gave birth to evolutionary theory and interactive learning theory of "system approach" (Nelson and Winter 1982; Nelson and Rosenberg 1993; Lundvall 1992; Freeman 1995) that propounds that innovation takes place through interactive learning in response to continuously changing economic, political and technological environment (Leydesdorff 2012). Chain-linked model, interactive learning model and triple-helix models of innovation are based upon this approach. These models along with linear model have been used as a basis for many innovation measurement studies (Ames 1961; Blackman et al. 1973; Pavitt 1982; Meyer-Krahmer 1984; Jalles 2010; Schwartz et al. 2012; Cruz-Cázares et al. 2013; Acs et al. 2013; Hoarau and Kline 2014; Santacreu 2015). These studies considered R&D expenditure and patents as two important indicators of innovation. Other streams of researchers (Kerssens-van Drongelen and Cooke 1997; Wong 2001; Gama et al. 2007) and organizations like PricewaterhouseCoopers (PwC 2011) have used performance measurements tool,

i.e. Balanced Scorecard (Kaplan and Norton 2001) to measure innovation performance of firms or enterprises.

Despite various concerns of policy-makers towards the role of universities and higher academic technical institutions in national innovation systems, very little attention has been given to measure and understand the process of innovation in these institutions. A common consensus has been noticed among researchers towards multi-dimensional nature of innovation which requires "system approach" of innovation measurement (Dewangan and Godse 2014). Langford (2002) in a theoretical analysis to identify the measurable proxies for the outcome of university research followed chain-linked model of innovation. The study identified institutionally managed spin-off and contract research as a measurable proxy for the outcome (effects or consequences) of university research on innovation. In another study, Langford et al. (2006) using a linear model identified peer-reviewed research grant, industry sponsorship investment as an input proxy; publication, patent and citation data as an output proxy and spin-off creation, technology licensing as outcome proxy.

It is clear from the extant literature that very little attention has been given on measurement of innovation by universities and higher academic technical institutions. Moreover, excessive emphasis has been given on R&D expenditure and patents as innovation indicators, neglecting all other possible indicators. This necessitates the development of a structural model that integrates classical and contemporary views of innovation to capture multi-dimensional aspect of innovation for higher academic technical institutions.

Linear model is very popular among researchers of innovation measurement due to its simplicity (Godin 2006) despites its critics. It provides a causal relationship (Rossi 2002) leaving aside complex functional and determinant mechanism (Guan and Chen 2010) of innovation. For the present study, we adopt the linear model of innovation to show the causal flow of activities. Non-linear elements like contribution of external agencies through collaboration and communication has been added to depict the interactive learning theory of systems approach of innovation. Various dimensions of innovation along with indicators depicting each dimension (with specific focus on innovation by academic institutions) have been identified through literature to build the conceptual framework.

3.3 Research Methodology

3.3.1 Development of Structural Model

A structural model is a diagrammatic representation of the elements of a concept and the connections between them (McLean and Shepherd 1976; Watson 1978; Lendaris 1980). Such models provide a useful "map" with different directions and links between inherent elements of a complex system (Lendaris 1979). These

models are different from statistical models that focus on grouping or clustering of elements through numerically identifying coefficients or weights. Structural models are necessary precursor of statistical or arithmetical models (Watson 1978) and are applied prior to looking at the statistical properties of various elements of a system and identifying their coefficients (Conant 1980). Mathematical quantitative aspects may be added to make this qualitative geographical depiction semi-quantitative (Sharma et al. 1995). Various structural modelling tools as described by McLean and Shepard (1976), Kawamura et al. (1976), Linstone et al. (1979), Lendaris (1980) and Sushil (2012) are: Interpretive Structural Modelling (ISM), Total Interpretive Structural Modelling (TISM), Qualitative Simulation (QSIM), KSIM, Spin, MICROBE, Elimination and Choice Translating Reality (ELECTRE), etc. These tools are based upon some assumptions like: elements of a system are given (Lendaris 1980) and experience-based knowledge or understanding of the problem is present in the minds of some groups of experts (Sharma et al. 1995). Structural modelling tool is performed in two phases: the first phase is the "generation" phase wherein list of elements pertaining to a particular concept are generated; the second phase is the structuring phase wherein structuring tools are used to establish relationship between all elements. For this study, the first phase involves extensive literature review and expert opinion while in the second phase ISM and TISM tool is used to identify and interpret the relationship among elements selected in the first phase.

3.3.2 Interpretive Structural Modelling (ISM) and Total Interpretive Structural Modelling (TISM)

A system can best be represented as directed graphs (digraphs) where parts are shown by nodes or points and their relationship is represented by a directed line. ISM is a tool that follows directed graph approach to build the hierarchical structure of a set of elements based upon the minimum of information about the pair-wise connections (Lendaris 1980). It is considered to be more suitable tool to deal with societal questions and more useful when the number of elements are relatively large (Warfield 1976; Lendaris 1980; Sharma et al. 1995). Moreover, its ease of use, simplicity of presenting comprehensible structure and rapid response makes it a popular tool among researchers of social science (Warfield 1982; Sharma et al. 1995). Hawthorne and Sage (1975) developed an interpretive structural model of a complex public and societal system like higher education system. They used man–machine environment where participants were involved in group discussion to understand the steps taken to develop an intent structure of higher education system in large metropolitan region. Similarly, this technique has been used widely in diverse fields of enquiry such as knowledge management (Tabrizi et al. 2010), product design and development (Hsiao et al. 2013), global warming, energy and environment (Ansari et al. 2013; Shi et al. 2015), productivity management

(Poduval and Pramod 2015) and supply chain management (Mandal and Deshmukh 1994; Diabat and Govindan 2011). TISM is an upgraded form of ISM where instead of just identifying appropriate relationships among elements, deeper and extended explanations are given for each links and nodes (Sushil 2012, 2016). It helps in giving the answer of "why" element of each relationship (Yadav and Sushil 2014).

3.4 Development Procedure for ISM

Various phases involved in ISM development are as follows:

Step 1: Identification and description of elements: It is the preliminary condition for the application of ISM. The elements in this study are indicators that can be used for the measurement of innovation by higher academic technical institutions.
Step 2: Development of Structural Self-Interaction Matrix (SSIM): This matrix is developed by taking the consensus of heterogeneous group of experts on the pair-wise relationship between various elements.
Step 3: Development of Initial reachability matrix: Initial reachability matrix is a binary matrix of zeros and ones that is developed from SSIM.
Step 4: Development of Final reachability matrix: This matrix is obtained after transitivity check of initial reachability matrix. As per transitivity rule, if an element X is impacting element Y and element Y is impacting element *Z* then element X must impact element Z.
Step 5: Level partition: This step involves identification of reachability set and antecedent set of elements as described in detail in the following sections.
Step 6: Development of hierarchical structure: Hierarchical structures are developed after removing transitivity based upon the conical matrix showing different levels of elements and their relationship.

3.4.1 Indicators of Innovation by Higher Academic Technical Institutions

There are two ways of looking at innovation: Innovation as a product (new or improved technology or product); Innovation as a process, i.e. sequence of activities that lead to the introduction of new and improved products (Pelz et al. 1978; Crossan and Appaydin 2010). In this study, we look at innovation as a process, consisting of various activities which complete not only with the introduction of new/improved product, process but involves its diffusion for commercial application and appropriation to take value out of it. The generic theoretical framework that has largely been adopted by scholars to measure innovation by higher academic technical

institutions consists of three components of innovation, i.e. innovation input, innovation output and innovation outcome. But, there is a conflict in the literature on the composition of each stage: some scholars consider R&D expenditure as innovation output (Pavitt 1982; Tohidi and Jabbari 2012) while it has been used as an input indicator by others (Blackman et al. 1973; Meyer-Krahmer 1984; Cruz-Cázares et al. 2013). Similarly, indicators like new process, new equipment; new technology have been used as output indicators by some (Abernathy and Clark 1985; Tohibbi and Jabbari 2012; Arundel and Huber 2013) and outcome indicators by others (Hoarau and Kline 2014). Thus, to deal with the ambiguity in the existing literature, we identify a list of indicators from the innovation literature and refine them further with expert's opinion to be applicable in Indian context. A list of indicators has been extracted from the innovation literature and is refined further with expert's opinion to be applicable in Indian context. The list with descriptions and references is given in Table 3.1.

(1) R&D fund: R&D fund is the crucial element to ensure that sufficient conditions for research and development exist in the institutions. It includes General University Fund (GUF), i.e. a part of university research that is financed by general grants from the Ministry of Education and is designed for both education and research (Frascati Manuel 2002).
(2) R&D staff: For higher academic technical institutions, total number of research personnel available in the form of Post Graduate (PG) students/PhD scholars/skilled technical staffs and post-doctoral students along with faculty members in the department form very important elements in the innovation process.
(3) R&D time: Faculty members along with research (project management, Ph. D. guidance) also utilize their time in class teachings, meetings, student's counselling and other administrative work (Ray and Saha 2010). The proportion of time a faculty member is devoting on research work forms a very crucial factor in the process of innovation.
(4) R&D facility: This indicator includes items such as lab area and number of standardized equipment as important factor that helps in providing new or improved solutions to various problems.
(5) R&D training: R&D training provides researchers with knowledge of various research tools, techniques, laboratory experiments and methods that increases their propensity to innovate (Bauernschuster et al. 2009).
(6) Collaborations and networking: Linkages of universities and higher academic institutions with industries and other research institutions act as indispensable source of information, ideas, technologies, practices and other resources for universities.
(7) Institutional policies: Presence of professionally managed IP management cell or technology transfer office and clear policies related with ownership of intellectual property rights, technology transfer, revenue sharing and others provide a strong signal of the supportive environment for the innovation in the institute.

Table 3.1 Indicators of innovation

No.	Indicators	Explanation	References
1	R&D fund	Funds received from government for research	Blackman et al. (1973), Pavitt (1982), Meyer-Krahmer (1984), Oslo Manual (2005), Langford et al. (2006), Fritsch and Slavtchev (2007), De Beule and Van Beveren (2008), PwC (2011), Frascati Manual (2002), Cruz-Cázares et al. (2013), Fu and Li (2014)
2	R&D staff	Total number of research personnel	Meyer-Krahmer (1984), Fritsch and Slavtchev (2007), Ray and Saha (2010), Cruz-Cázares et al. (2013), GII (2014)
3	R&D time	Proportion of time faculty devotes to research	Ray and Saha (2010)
4	R&D facility	Number of labs and equipment	Frascati Manual (2002)
5	R&D training	Research specific courses to PhD students	Bauernschuster et al. (2009)
6	Collaborations and networking	Students' projects funded by industry, MoU with industry or with foreign universities	Goes and Park (1997), Tsai (2001), Frascati Manual (2002), Oslo Manuel (2005)
7	Institutional policies	Institute level policies related to IP, licensing, technology transfer	Owen-Smith and Powell (2001), Jensen and Thursby (2004), Oslo Manuel (2005)
8	Locational factor	Proximity of institutions to industrial parks or special economic zones	Nelson (1986), Jaffe (1989), Anselin et al. (1997), Friedman and Silberman (2003), Chapple et al. (2005), Hsu et al. (2015)
9	Research linked incentives	Research linked awards/prizes/incentives given to students and faculty by the institute	Dasgupta and David (1994), Arundel (2001), Cohen et al. (2002), Lach and Schankerman (2008)
10	Publications	Number of peer-reviewed journal publications	Oslo Manuel (2005), Langford et al. (2006), Schwartz et al. (2012)
11	Patents	Number of patents filed and granted in IPO/USPTO/EPTO	Ames (1961), Meyer-Krahmer (1981), Pavitt (1982), Ginarte and Park (1997), Acs et al. (2002), Oslo Manual (2005), Langford et al. (2006), Jalles (2010), Schwartz et al. (2012), Cruz-Cázares et al. (2013)
12	Sponsored projects and consultancies	Industrial research projects and consultancies by faculty members	Mowery et al. (1996), Langford et al. (2006), Eom and Lee (2010), Schwartz et al. (2012)
13	Citations	Number of forward citations to patents and publications	Jaffe (1989), Griliches (1991), Jaffe et al. (1992), Jaffe and Trajtenberg (1996), Redner

(continued)

Table 3.1 (continued)

No.	Indicators	Explanation	References
			(1998), Hall et al. (2001), Nemet and Johnson (2012)
14	Licensing/sale of technology	Patented technologies sold or licensed	Massaro (1996), Jensen and Thursby (1998), Balconi et al. (2004), Janeiro et al. (2013)
15	Spin-offs	New businesses incubated	Nelson (1986), Langford et al. (2006)
16	Contribution in national development goals	Participation of faculty in inclusive-innovation/grass-root innovation projects, policy inputs given by faculty resulted in innovative changes at grass-root level	Kakodkar Committee Report (2011)

(8) Locational factors: Positive impact of university research on the industrial innovation and start-ups has been found by Jaffe (1989), Nelson (1986) and others. Presence of industrial parks or Special Economic Zones (SEZ) in close proximity with the institutes can advance institute's research activity by providing various research ideas.

(9) Research linked Incentives: It involves research-based rewards given to R&D staff (students and faculty) and number/quantity (amount)/type.

(10) Publications: Scientific publications in peer-reviewed journals are literature-based indicator of innovation output (Oslo Manual 2005). Along with this variable, other variables to capture publication and its quality are: impact factor per faculty and h-index per faculty.

(11) Patents: A patent is the legal property right to the invention, granted by national patent office (Oslo Manual 2005). Variables to capture this indicator are total number of individual and joint patents filed, total number of patents granted, fraction of patents granted to patents applied, i.e. Granted/Filed.

(12) Sponsored projects and consultancies: This variable is measured by items like number and value (in monetary terms) of projects that are sponsored by internal sources, external sources and number and value (in monetary terms) of research consultancies provided to industries.

(13) Knowledge transfer: Forward citations become a measure of knowledge spill-over through patents and publications where new researchers take ideas and build upon them to further innovate.

(14) Technology transfer: New technology created by academic institutions may get transferred to industrial organizations through licensing or sale of patents. It is a market mediated channel of technology transfer where two or more parties enter into an agreement to transfer invented technology for its wider application.

(15) Entrepreneurship development: Number of technology business incubated out of patented/unpatented technology, number of biotech business incubated (patented/unpatented technology based) and number of entrepreneurship courses developed.

(16) Contribution in national development goal: Innovation is not only needed in technology and business, but also in society (Kakodkar Committee Report 2011). Universities and higher academic technical institutions lay down the path and direction to move ahead by participating in social development projects and providing policy research inputs. Examples of such contributions are participation in National Bamboo Mission Projects, National Biomass Cookstove Initiatives, Spectrum Aware Rural Connectivity program (SPARC), etc. and various policy inputs that results into many innovation-based programs.

3.4.2 Structural Self-interaction Matrix (SSIM)

In this step, mental models of interaction between elements are converted into communicable form through structural self-interaction matrix (Hawthorne and Sage 1975). This matrix shows "pair-wise relationship" of elements (arranged in rows–columns) that is obtained through consensus building among heterogeneous group of experts. This exercise greatly enhances the discernment and communication among researchers and experts. To know the constitution of a system with N elements $N(N-1)/2$ pairs are examined (Watson 1978). In this study for 16 elements, 120 paired comparisons are made.

Theoretical population of experts for this study involves academicians, practitioners or professionals based in India who are directly involved in academic innovation based research, practice or profession for more than 5 years. 23 experts were selected through judgement sampling and profile search. Group of experts include academicians, Intellectual Property (IP) professionals in government and private organizations, technology transfer professionals and policy researchers. Special care was taken to ensure that all experts have rich and relevant expertise in innovation related studies. Out of 23 experts, 8 experts agreed to participate in the study forming 34% response rate which is an acceptable proportion for ISM based study (Jharkaria and Shankar 2004, 2005). An online matrix was mailed to all experts along with the cover letter mentioning the motive of research and indicating directions to fill the matrix. All responses received from experts were collated and compared to find the commonality.

In the matrix, if elements in rows are represented by i and elements in columns by j then symbols used to represent the direction of relationship are: $V = i$ influences j; $A = j$ influences i; $X = i, j$ influence each other; O = no relations. For an element A, a symbol was assigned based upon the consensus of 70% of experts. Table 3.2 shows the structural self-interaction matrix developed from expert's opinion.

Table 3.2 SSIM

S. No.	Indicators (*i*)/(*j*)	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	R&D fund	V	V	V	O	V	V	V	V	O	O	V	V	V	V	V	1
2	R&D staff	V	V	V	V	V	V	V	V	A	A	V	V	X	X	1	
3	R&D time	V	V	V	V	V	V	V	V	O	O	V	V	X	1		
4	R&D facility	V	V	V	V	V	V	V	O	A	A	V	V	1			
5	R&D training	V	V	V	V	V	V	V	O	O	A	A	1				
6	Collaboration and networking	V	V	V	V	A	V	V	A	A	A	1					
7	Institutional policies	V	V	V	O	V	V	V	V	O	1						
8	Locational factor	V	V	V	O	V	V	O	O	1							
9	Research linked incentives	V	V	A	A	V	V	V	1								
10	Publications	V	V	O	V	A	A	1									
11	Patents	V	V	V	V	X	1										
12	Sponsored projects and consultancies	V	V	X	O	1											
13	Citations	O	O	V	1												
14	Licensing/sale of technology	V	V	1													
15	Spin-offs	X	1														
16	Contribution to national development goals	1															

3.4.3 Initial Reachability Matrix

Initial reachability matrix is a binary matrix that is formed by converting the symbols V, A, X and O into a matrix of 0s and 1s. Rules for the conversion of SSIM into reachability matrix are given in Table 3.3.

Based on the above mentioned rule, an initial reachability matrix is developed as given in Table 3.4.

Table 3.3 Rules to convert SSIM into initial reachability matrix

Entry in SSIM	Entry in initial reachability matrix	
	(*i, j*)	(*j, i*)
V	1	0
A	0	1
X	1	1
O	0	0

Source Jothimani et al. (2015)

Table 3.4 Initial reachability matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	*1*	*1*	*1*	*1*	*1*	*1*	*0*	*0*	*1*	*1*	*1*	*1*	*0*	*1*	*1*	*1*
2	*0*	*1*	*1*	*1*	*1*	*1*	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
3	*0*	*1*	*1*	*1*	*1*	*1*	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
4	*0*	*1*	*1*	*1*	*1*	*1*	*0*	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
5	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
6	*0*	*0*	*0*	*0*	*1*	*1*	*0*	*0*	*0*	*1*	*1*	*0*	*1*	*1*	*1*	*1*
7	*0*	*1*	*0*	*1*	*1*	*1*	*1*	*0*	*1*	*1*	*1*	*1*	*0*	*1*	*1*	*1*
8	*0*	*1*	*0*	*1*	*0*	*1*	*0*	*1*	*0*	*0*	*1*	*1*	*0*	*1*	*1*	*1*
9	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*1*	*1*	*1*	*1*	*0*	*0*	*1*	*1*
10	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*1*	*0*	*1*	*1*
11	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
12	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*1*	*1*	*1*	*0*	*1*	*1*	*1*
13	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*0*	*1*	*1*	*0*	*0*
14	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*0*	*0*	*1*	*0*	*1*	*1*	*1*
15	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*
16	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*	*1*

3.4.4 Final Reachability Matrix

This matrix is obtained after transitivity check of initial reachability matrix. As per transitivity rule, if an element A is impacting element B and element B is impacting element C then element A must impact element C. For each such transitive link entries 0^s are converted into 1^s and driving and dependence power of each variable is calculated. Driving power (**Dr. P**) of an element signifies total number of elements that get impacted by the concerned element (add all 1^s in each row) and dependence denotes total number of elements from which the concerned element gets impacted (add all 1^s in each column). Identification of dependence power and driving power of each element helps in categorization of elements as dependent, independent, autonomous and linkage factor. This categorization has been explained in detail in later sections. Table 3.5 shows the final reachability matrix with its driving power and dependence.

3.4.5 Level Partition

Final reachability matrix is used to assign different levels to elements through the antecedent and the reachability sets of each element (Warfield 1974). For an element "A" reachability set consists of itself and all other elements that may get

Table 3.5 Final reachability matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Dr. P
1	1	1	1	1	1	1	0	0	1	1	1	1	1_a	1	1	1	14
2	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	13
3	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	13
4	0	1	1	1	1	1	0	0	1_a	1	1	1	1	1	1	1	13
5	0	0	0	0	1	1_a	0	0	1_a	1	1	1	1	1	1	1	10
6	0	0	0	0	1	1	0	0	1_a	1	1	1_a	1	1	1	1	10
7	0	1	1_a	1	1	1	1	0	1	1	1	1	1_a	1	1	1	14
8	0	1	1_a	1	1_a	1	0	1	1_a	1_a	1	1	1_a	1	1	1	14
9	0	0	0	0	1_a	1	0	0	1	1	1	1	1_a	1_a	1	1	10
10	0	0	0	0	1_a	1_a	0	0	1_a	1	1_a	1_a	1	1_a	1	1	10
11	0	0	0	0	1_a	1_a	0	0	1_a	1	1	1	1	1	1	1	10
12	0	0	0	0	1_a	1	0	0	1_a	1	1	1	1_a	1	1	1	10
13	0	0	0	0	1_a	1_a	0	0	1	1_a	1_a	1_a	1	1	1_a	1_a	10
14	0	0	0	0	1_a	1_a	0	0	1	1_a	1_a	1	1_a	1	1	1	10
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2

Note a Transitive relationship

affected by it (have 1^s in corresponding row) while antecedent set is a set that consists of element itself and all those elements that may affect it (have 1^s in corresponding columns). These two sets are used to get an intersection set that consists of common elements of reachability and antecedent set. Elements for which reachability and intersection set is same are assigned same level and are eliminated from the list for further analysis. This step involves several iterations until all elements are assigned some level. Details of iterations performed to do levelling are given in the Appendix. Table 3.6 shows a list of all elements with level partition.

3.4.6 Development of Hierarchical Structure

Elements which are at the first level are given the top most position in the hierarchical structure and they impact only each other but not any other element in the list. Elements which are at the last level, in this case at the fourth level, impact all other elements in the list but not get impacted by any other element. Elements in the middle levels impact other elements in the same level and also those in the level above it but get impacted by the elements below it (Fig. 3.1).

Above hierarchal structure for innovation by higher academic technical institutions shows that indicators 1, 7 and 8, i.e. R&D funds, locational factors and institute's policies are most important factors (driving factors) for innovation which impact all other R&D related activities directly or indirectly. Supportive institutional policy related with intellectual property that is linked with rewards, incentives, promotion and career advancement directly influences employee's motivation to invest time on research activities. Similarly, availability of sufficient funds, exclusively for R&D purpose directly ensures availability of research staff and facilities and indirectly it impacts other research, patenting, collaboration and networking activities. Proximity of institute with industrial zone further leads to better research facilities in the institute through setting up of collaborative research labs and joint venture projects.

Second level indicators, i.e. R&D time, staff and facilities impact all other important indicators of university innovation, i.e. patenting, publication, collaborative research, citation, etc. Not only this, they also get impacted by each other. Various factors of R&D staff like age, experience, research attitude and motivation impacts time spent on R&D activities at the workplace. Similarly, in a multi-tasking environment, R&D time, i.e. overall time required to be spent on research activities determines number and quality of research personnel. Better R&D staff and their ability to deal with high-end and sophisticated instruments will ensure better R&D facilities, i.e. more number of research labs and facilities. Similarly, better facilities will in turn attract high quality research personnel. These three factors along with R&D fund, location and institutional policy lead to institutes' orientation towards collaboration, networking, joint projects, publications, patents, etc.

Table 3.6 Level partition

Element	Reachability set	Antecedent set	Intersection set	Level
15	15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15, 16	I
16	15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15, 16	I
5	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
6	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 12, 14	5, 6, 9, 10, 11, 12, 13, 14	II
9	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
10	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
11	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
12	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
13	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
14	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
2	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
3	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
4	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
1	1	1	1	IV
7	7	7	7	IV
8	8	8	8	IV

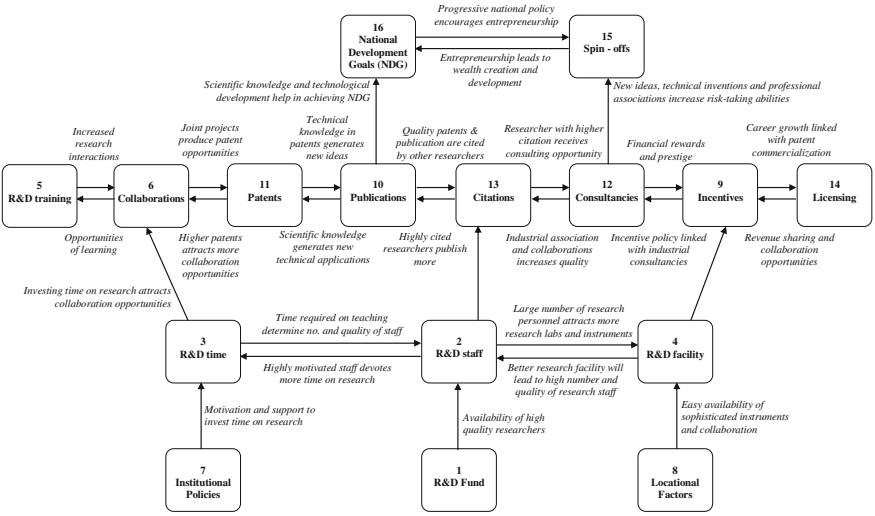

Fig. 3.1 TISM model without transitive links

Third level indicators, besides impacting higher level indicators, also impact each other. Type of training provided to research staff ensures research collaboration which in turn brings incentive in the form of new learnings, joint projects, collaborative publications and consulting opportunities, etc. Quality of research publications or patents will ensure higher citations and licensing opportunities. Similarly, higher citations and technology licensing will further increase researcher's reputation and pave the way for more collaborative research and hence publication or patents.

Factors 15 and 16, i.e. entrepreneurship activities and institute's contribution in national development goals are top level indicators which get impacted directly or indirectly by every other indicators. Patents on new inventions, technical opportunities and collaborations motivate research personnel or research students to undertake risk and start entrepreneurial activities. Entrepreneurship further pave the way for wealth creation, provide job opportunities and help in achieving national development goals.

3.4.7 Indicators' Classification

After classification of elements into different levels we position them on the basis of their strength or importance through MICMAC technique, i.e. *Matrice d'Impacts croises-multipicationapplique' an classment* (cross-impact matrix multiplication applied to classification) (Saxena et al. 1990; Sharma et al. 1995; Ansari et al. 2013; Jothimani et al. 2015). Based upon the conical matrix given in the Table 3.5 we

identify the driving and dependence power of elements by adding total number of 1^s in rows and columns, respectively, (Singh et al. 2003). The elements are then plotted on a two dimensional graph with driving powers plotted on *Y* axis and dependence powers of elements are plotted on *X* axis. A driving dependence power matrix is obtained which is then divided into four segments keeping in mind the maximum driving and dependence powers (Sharma et al. 1995). Variable's driving power and dependence power is then plotted on the matrix and are classified into four categories, i.e. dependent, independent, autonomous and linkage variables.

(1) Dependent variables: Dependent variables are those variables that have low driving power but very high dependence.
(2) Independent variables: Independent variables are those that have strong driving power but weak dependence.
(3) Autonomous variables: These variables have neither enough driving power nor dependence in the system.
(4) Linkage variables: These variables have both—high dependence and high driving powers and impacts other variables besides getting affected by some others.

As shown in the Fig. 3.2, out of 16 indicators of innovation by higher academic technical institutions in India six indicators namely R&D fund, R&D staff, R&D time, R&D facility, institute's location and policies are the key independent variables. These variables along with linkage variables like R&D training, research linked incentives, publications, patents, industrial collaborations, consultancies, licensing and citations help universities or institutes in entrepreneurship development and contribution in national development goals.

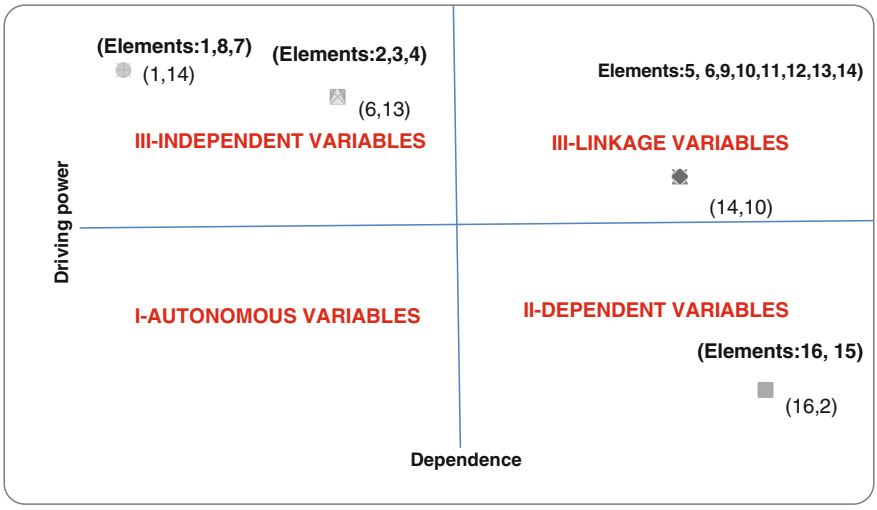

Fig. 3.2 Classifications of elements through *MICMAC* technique

3.5 Conclusion

This study is an effort to develop a structural model that identifies the key elements and process of innovation in higher academic technical institutions. It provides a framework for the measurement of innovation performance in these institutions. This model reveals that the innovation process in an academic institution takes place in four different stages or levels. Each level contains a set of interactive indicators that not only impacts other indicators of that level but also gets impacted by them. Patents, publications, industrial consultancies, sponsored projects, research linked incentives and training act as strong linkage indicators that connect the final outcomes like entrepreneurship development and national development goals with the research inputs like funds received from the government, amount of time, facility and personnel devoted for research, Institute's location and IP related policies. It also solves the ambiguity on the treatment of variable as an input, output or outcome variable.

With the increased allocation and mobilization of public resources to encourage innovation in universities and higher academic technical institutions, this chapter has an implication for both policy-makers and academicians. The structural model developed here will act as a useful tool for the measurement of research and innovation efficiency of different universities or institutes. Identification of relationship among various indicators of innovation and their categorization into different hierarchy helps in understanding the sub-processes of the whole system. It will also be used for the analysis of efficient utilization of overall resources that are allocated to different universities or institutes. In effect, it will provide guidance to the policy-makers about how to further allocate resources based upon the past performance of higher academic technical and research institutions.

Appendix

1. **Iteration 1 for Level Partition**

	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1	1	
2	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 7, 8	2, 3, 4	
3	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 7, 8	2, 3, 4	
4	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 7, 8	2, 3, 4	
5	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	
6	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 12, 14	5, 6, 9, 10, 11, 12, 13, 14	
7	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16	7	7	
8	2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 16	8	8	
9	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
10	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
11	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
12	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
13	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
14	5, 6, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	3, 4, 5, 6, 9, 10, 11, 12, 13, 14	
15	15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15, 16	I
16	15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15, 16	I

2. **Iteration 2 for Level Partition**: After removing 15, 16 variables from the sets

	Reachability set	Antecedent set	Intersection	Level
1	1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14	1	1	
2	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 7, 8	2, 3, 4	
3	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 7, 8	2, 3, 4	
4	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 7, 8	2, 3, 4	
5	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
6	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 12, 14	5, 6, 9, 10, 11, 12, 13, 14	II
7	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14	7	7	
8	2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14	8	8	
9	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
10	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
11	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
12	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
13	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II
14	5, 6, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14	5, 6, 9, 10, 11, 12, 13, 14	II

3. **Iteration 3 for Level Partition**: After removing 5, 6, 9, 10, 11, 12, 13, 14 variables from the sets

	Reachability set	Antecedent set	Intersection	Level
1	1, 2, 3, 4	1	1	
2	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
3	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
4	2, 3, 4	1, 2, 3, 4, 7, 8	2, 3, 4	III
7	2, 7	7	7	
8	2, 8	8	8	

4. **Iteration 3 for Level Partition**: After removing 2, 3, 4 variables from the sets

	Reachability set	Antecedent set	Intersection	Level
1	1	1	1	IV
7	7	7	7	IV
8	8	8	8	IV

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Part II
Flexibility in Organizational Management

Chapter 4
Network Science in Logistics: A New Way to Flexible Adaptation

Fekete István and Hartványi Tamás

4.1 Introduction

In this chapter, we investigate the characteristic patterns, network structure of demand-supply network (DSN). In supply chain literature, we may come across terms supply chain network, supply network and demand-supply network. While the first two cover practically the same thing, the latter also puts emphasis on demand flow through the network of organizations. We will use these terms in our article accordingly. The literature on supply chain networks focuses more on a network's throughput maximization or optimization (Chen et al. 2009). The other large field is the supply chain networks' disruptions and the heuristics on building resilience (Vitasek et al. 2003). The network structure of the supply chain and the behaviour caused by that topology is investigated poorly, especially in case of the network element, i.e. the organization. We focus more on that level of representation. The important introduced network science terms will be stated in bold at its first occurrence.

4.2 Coarse-Grained Representation of Demand-Supply Network (DSN)

In demand-supply network (DSN) representation, the organizations play dual roles. As customers, they buy different resources for their material/value conversion process, and convert those into sellable values/products/services—see Fig. 4.1.

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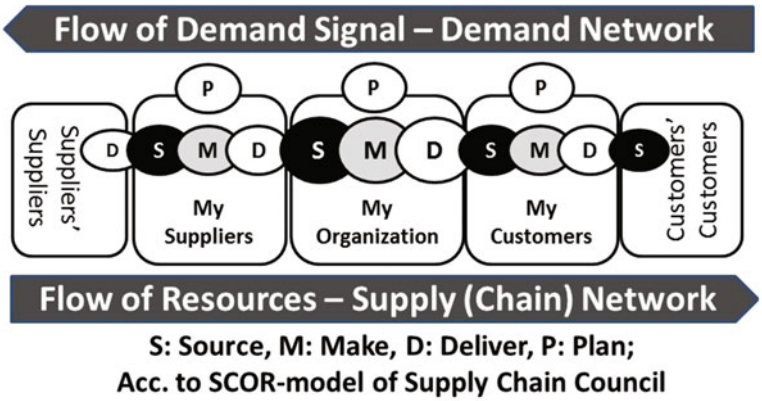

Fig. 4.1 Deliver-source interactions as links and organizations as nodes form complex DSN

They sell those to other organizations/customers. In the Supply Chain Council's SCOR model, 'My Organization' triggers the resources from suppliers through 'Source' process, which in turn is the 'Deliver' process for a supplier. After converging the resources into valued finished products ('Make' process), the organization delivers those to its customer/s. Through those 'deliver-source' links, the companies form a complex directed network where the (added)-value flows from supplier to customer (Supply Chain Council SCOR 2011). In fact, apart from materials, there are several 'things' exchanged between companies, e.g. information, machines/tools, money, etc. We focus on materials and on-demand of materials.

The DSN is mostly acyclic but also a mixed directed/undirected multipartite network, and a bit more complex than the mixed directed/undirected tri-partite metabolic networks. In very small portions, there are reverse flows of materials—from customer to supplier: e.g. non-quality product return, reverse logistics, internal and external recycling, etc. DSN is also a man-made and engineered network, as is the Internet, with no central control on a network level (Palotai and Csermely 2009; Newman 2010).

4.2.1 Network Topology of Demand-Supply Network (DSN) and Its Behaviour

In the case of coarse-grained representation, organizations form the nodes of DSN, and a great number of in-links and out-links connect the two adjacent organizations. The DSN's coarse-grained representation is a multi-edge directed weighted graph. Since the dependences occur on exchanged materials, and other resources,

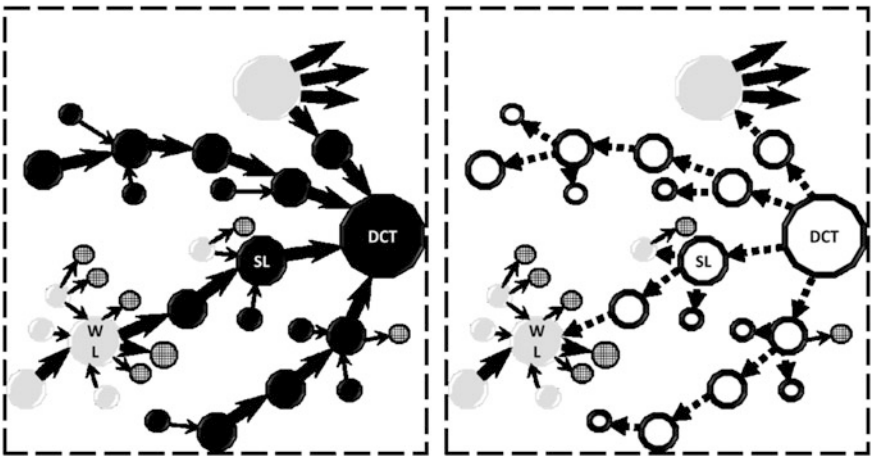

Fig. 4.2 Star-shape network topology in the neighbourhood of a dominant organization

information, etc., the most relevant network topology can be analysed in finer grained representation.

In DSN, the dominant organizations may dictate to their adjacent suppliers and customers in few-steps' distance (tiers in supply chain terminology). There is strong alignment to dominant, dictating player—e.g. OEM—effects through 2–4 Tiers/Steps and it creates a star-shape network topology around the dominant organization. See Fig. 4.2. In such topology, the value stream optimization, driven by a dominant player, is very effective and the Multi-Echelon Inventory Optimization (MEIO) also works well. The demand signal advances upstream undistorted. Such a supply chain usually is called by Gartner as the 'Best supply chain of the year'. However the star-shape network topology also creates disadvantages. The strongly linked and aligned suppliers are heavily dependent on a dominant organization. The fluctuation of the dominant organization may disperse through the network as a disruption. Often there are digital survival chances for smaller suppliers at the end of the chains. If the central dominant player collapses then the entire star-shape network will be fragmented and the strongly aligned and linked companies will be heavily affected. Some weakly linked companies may survive.

4.2.2 Supply Flow in DSN Versus Transport Process in Biochemical Networks

The DSN, in its complexity, is rather different from transportation, delivery or distribution networks and is more similar to the combination of metabolic networks and of protein–protein interaction networks (Antal et al. 2009; Newman 2010). In

metabolic networks, the nodes are metabolites, while in DSN those are the materials and products. The former's substrates are the latter's raw materials; the former's products are also called (finished) products in the latter. Enzymes in metabolic networks are the enablers, likewise men, machines and energy in DSN. The flow of supply in DSN is analogue to the transport process in biochemical networks. Further analogies were established by the authors (Fekete and Hartványi 2014). Both DSN and biochemical networks are multipartite directed networks.

4.2.3 Demand Flow and Planning in DSN Versus Signalling Pathways and Hetero-catalytic Regulatory Processes in Biochemical Networks

The communication and regulatory processes covered mainly by 'Plan' process in the SCOR Model. The demand signal in DSN flows from customer to supplier in the opposite way to the flow of materials (see Fig. 4.1). The demand signal may be represented in the internal regulatory processes as a physical, visual change due to physical interactions, e.g. physical Kanban, or physical standard WIP in production cell. Prof. Csermely and Palotai made the overall generalization of the above aspect: network signalling can be considered as highly specialized case of transport process (Palotai and Csermely 2009). These regulatory processes also show similarities with regulatory enzyme concentration level dynamics in hetero-catalytic regulatory processes (Smith and Szathmáry 1999; Newman 2010).

4.3 Three Adjacent Levels of Granularity to Be Investigated

In most cases, we can investigate an organization's internal structures at a detailed level, i.e. fine-grained representation; while we may have limited access to the organization's external structure. The links of supply from the organization's suppliers and to its customers are usually well known but the mid- or fine-grained structure of suppliers or customers are barely known. That asymmetry in our knowledge will be reflected in our objects of investigation. This approach is similar to the systems analytical approach in complex geological mapping developed by one of the authors in early 1990s (Fekete 1992). Newman emphasizes that in metabolic networks usually the right level of investigation is neither the whole network (of extreme complexity) nor the individual reactions but the metabolic pathways (Newman 2010). The introduction of the network element by Csermely ('complex node' having networked internal structure) enables us to deal with complexity and focus on modules (more densely connected network parts), network skeleton of high importance nodes—hubs, bridges, creative elements,

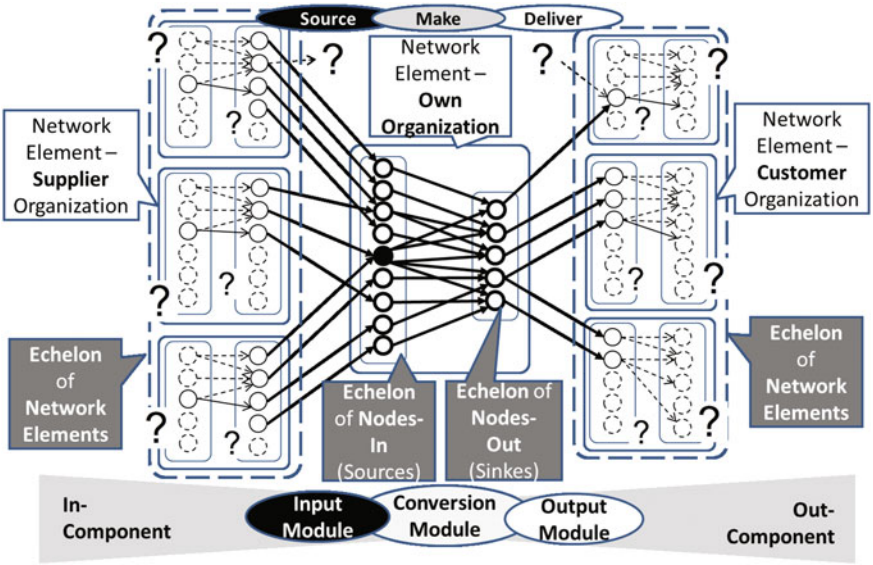

Fig. 4.3 The three levels of granularity when investigating the organization

high-weight/high-centrality nodes, etc. (Antal et al. 2009). A similar approach has to be used in DSN where, apart from the longitudinal pathways, it is worthwhile to investigate the transversal groupings too, which are called echelons in the supply chain theory (Snyder and Shen 2011). Typical echelons in our investigations are of suppliers, of resources (materials, machines, men, etc.), of finished goods/products and of customers (Fig. 4.3).

We suggest distinguishing input-, conversion- and output modules in the organization. The input module is built up by: (1) Supplier nodes (in fact, network elements without a clear internal structure); (2) Nodes-in (called sources of the material conversion process, i.e. resources), which an organization buys from its suppliers; (3) Links from supplier nodes to nodes-in/sources. The output module is built up by: (1) Nodes-out (called sinks of the material conversion process, i.e. finished goods/products), which the organization sells to its customers; (2) Customer nodes (network elements without a clear internal structure); (3) Links from sinks/nodes-out to customer nodes. The conversion module overlaps both the input and output modules, and is built up by: (1) Sources/nodes-in; (2) Sinks/nodes-out; (3) Links between those two groups of nodes (Fig. 4.3).

Important network science terms are the in-component and out-component (Newman 2010). The in- and out-components of a source node or a sink node and of an organization—the two adjacent hierarchic levels—are evidently different. The in-component of organization at the meta-level consists of all the in-components of sources/nodes-in, while the organization's out-component is built up by the out-components of sinks/nodes-out respectively (Fig. 4.3).

4.4 Network Characteristics of an Organization and Caused Behaviour

We investigated a number of companies from different industries and in all cases, the so-called fat-tailed scale-free out-degree distribution of sources and sinks is detected, i.e. of materials and finished goods/products (Fekete and Hartványi 2014). This type of distribution is widespread across living networks. The top 2–5 high-degree nodes have ranking stability, similar to the phenomenon described by Bianconi et al. (2008), Ghoshal and Barabási (2011). The scale-free distribution is a result of longitudinal optimization alongside the supply chain (e.g. late customization), while the ranking stability of high-degree nodes is due to transversal optimization of technology and preferential attachments (e.g. a successful component is used in new products) similar to the phenomena in biochemical and social networks described by Barabási and Csermely (Barabási 2002), Csermely (2009). In contrast, the in-degree distribution of sources and sinks show normal or Poissonian degree distribution and rarely close to a scale-free one. The so-called recursive modularity contributes to network stability in biochemical and other networks. This phenomenon is also widespread in the case of organizations—a detailed explanation was described in our earlier publication (Fekete and Hartványi 2014).

4.4.1 Visualization of Group Behaviour of Links of Node/Network Element

One of the authors developed convergence and divergence symbols to visualize complex structures of (networked) systems (Fekete 2003). Those symbols can also be utilized in visualizing the group behaviour of in- or out-links of a node in order to grasp the main characteristics of the links' behaviour (Fig. 4.4).

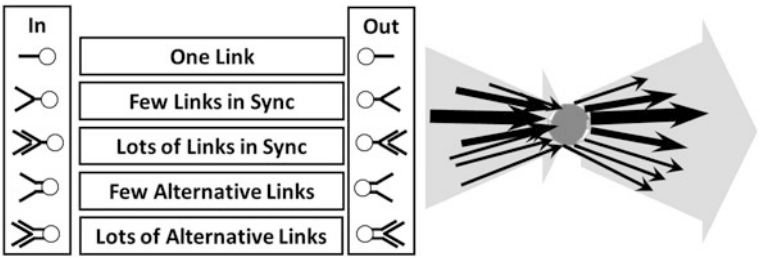

Fig. 4.4 Group behaviour of links of node/network element—transversal sync/asynchrony

4.4.2 Transversal Sync, Transversal Asynchrony and the Resulted Behaviour

We call transversal sync or asynchrony when it is perpendicular to material/value flow (in Echelon), while longitudinal sync or asynchrony when it is alongside the material/value flow. Strogatz and Csermely in their fundamental monographs describe a great number of syncs and also highlight the importance of sync in living networks (Strogatz 2003; Csermely 2009).

Our method with Combined Quantity Irregularity Graphs shows a clear correlation between the behaviour of a node and the structure of its out-component. Nodes with a large downstream out-component combined with transversal synch (e.g. promotions, focused marketing activities) have large but irregular quantities—causing disruptions in their environment, i.e. a source of large perturbation (Fig. 4.5, P89/DNI). Another case is when two nodes have a similar/same (downstream) out-component, e.g. kitting operations of materials for the same finished goods/products. Other large volume nodes have a large downstream out-component combined with transversal asynchrony (demand pooling), which makes their quantities regular—and may create stability for their environment, i.e. commonality as opportunity for creating dissipative behaviour. The transversal

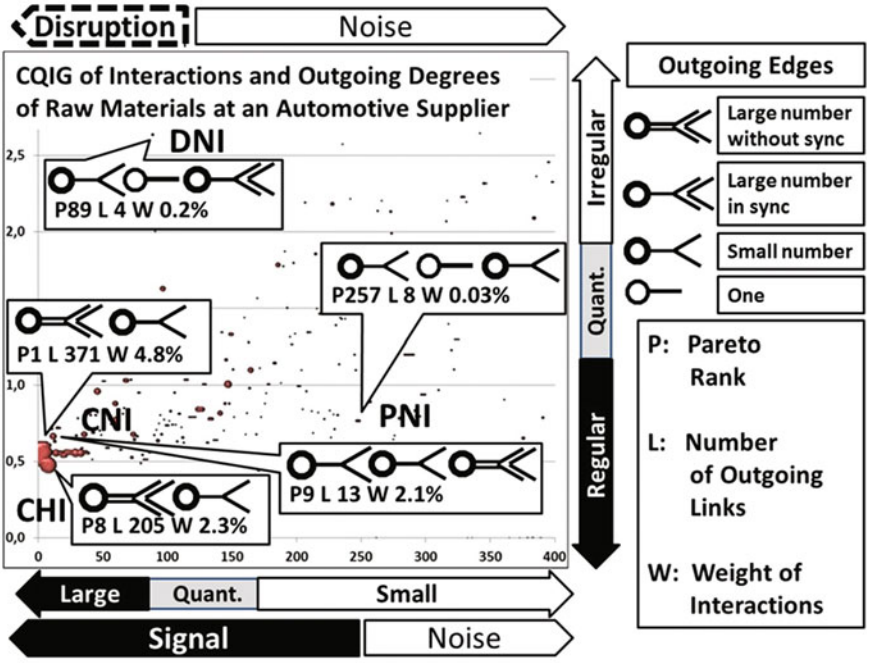

Fig. 4.5 Transversal sync and asynchrony in out-component and the resulted behaviour (the three-character coding is explained in Fig. 4.7)

asynchrony in this case may occur either directly at a given node (Fig. 4.5, P1, P8/CHI) or indirectly a few steps further downstream in the out-component of that node (Fig. 4.5, P9/CNI). Small volume items may have regular or irregular quantities depending on their downstream out-component's life cycle (Fig. 4.5, P257/PNI) (Fekete and Hartványi 2013).

4.4.3 The Multipartite Structure of the Organization

The network of an organization contains different nodes/network elements. Figure 4.6 illustrates those key node/network element types and their inter-relationship. Those nodes are forming the subnetworks of the organization of the same spatial extent. The (raw) materials are converted into (finished) products with the help of men and machines. Therefore, the links between the material and product nodes are directed, while between the latter and the man and machine nodes are symmetrical/undirected. Sometimes, it is reasonable to distinguish separately the more generic equipment from the more product specific tools in our investigations.

In such a case, as a rule, the tool has a stronger, more direct interaction with the (finished) product than the generic equipment—like a specific mould and the generic press equipment. Solid line links emphasize the strong dependence between the nodes—the thicker the link the stronger the dependence. The dashed line links are usually more transient or indirect, e.g. the interaction between man and tool runs only at the tool change. When determining the network skeleton of the organization, the majority of high weight/high importance links and nodes will be selected from the material-subnetwork first. However, nodes of other subnetworks will be included as well, e.g. critical machine nodes.

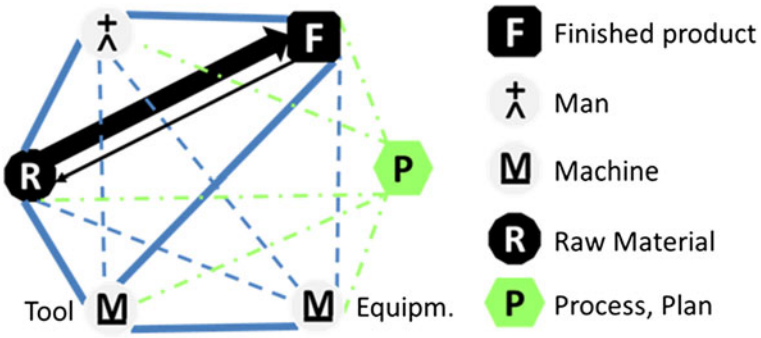

Fig. 4.6 Multipartite structure of the organization

4.5 Weak Sync, Weak Links Stabilize the Organization

Longitudinal strong sync and strong links are widespread in DSN. The Just-in-Time deliveries are synced alongside the demand and supply chain and in the case of Just-in-Sequence also with transversal sync. Since these are (over)stretched transport routes they pave the paths for cascading failures. Demand-supply mismatch causes a destabilized node as source of disruption/perturbation. Such mismatch occurs when either the supply- and/or the demand flexibility is missing or smaller than the fluctuation of demand and/or supply. Therefore, we focus more on how to create weak links and weak sync in the DSN, especially within the organization or at links towards suppliers and customers. Csermely proved that weak linkage plays a crucial role in stabilizing the network against/after disruptive perturbations (Csermely 2009).

4.5.1 Demand Flexibility Granted by Sink to Source

Demand flexibility is quite rare in DSN. It occurs when an organization can create a so-called 'Blue Ocean Strategy', i.e. it is dictating to its customers (e.g. Apple IPhone launches) and the customers wait or order early (Kim and Mauborgne 2005). Figure 4.7 shows the symbols we use to visualize the key characteristics of the investigated network structure and the behavioural node archetypes. The latter ones with their links build up the network skeleton of the organization.

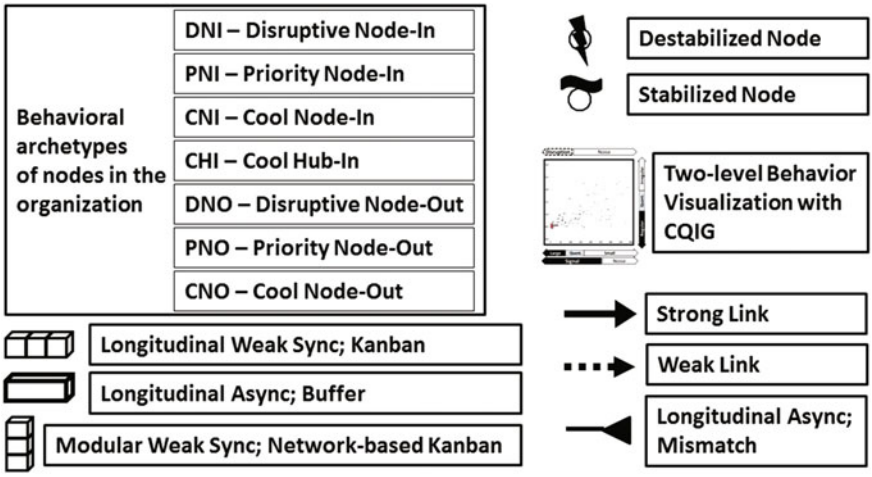

Fig. 4.7 Symbols for visualizing the network skeleton of the organization

4.5.2 Cascading Failure Through Strong Links in Organization and Beyond

The in-links of sinks (finished product nodes), which consume the resources from sources, are always considered strong. The out-links of sources (of materials, machines, etc.) are strong at the time of interaction between the source and sink nodes. However, when defining the strength in time then a given out-link of a source may be considered as weak (less probable), and also in the case of out-links of a dating-hub. This asymmetry in the links' strength acts as disruption trap, and will be described later. The typical behavioural node archetypes and links of the organization's network skeleton are highlighted in Fig. 4.8.

The disruption in DSN spreads at the time of/through interactions, i.e. when a given link is symmetrically strong-strong in time-space. In Fig. 4.8, the disruption enters from the customer to our organization through a Disruptive Node-Out (DNO) and spreads through strong links both upstream and downstream affecting all the node archetypes except for CHI and the relevant suppliers and customers. Such a cascading failure was detected by authors in an IT-Telecom organization, which nearly knocked it down.

4.5.3 Weak Sync Granted by Source to Sink—Supply Flexibility

Supply flexibility is far more widespread in Supply Chain Networks, as mostly the supply is adjusted to demand and not the contrary.

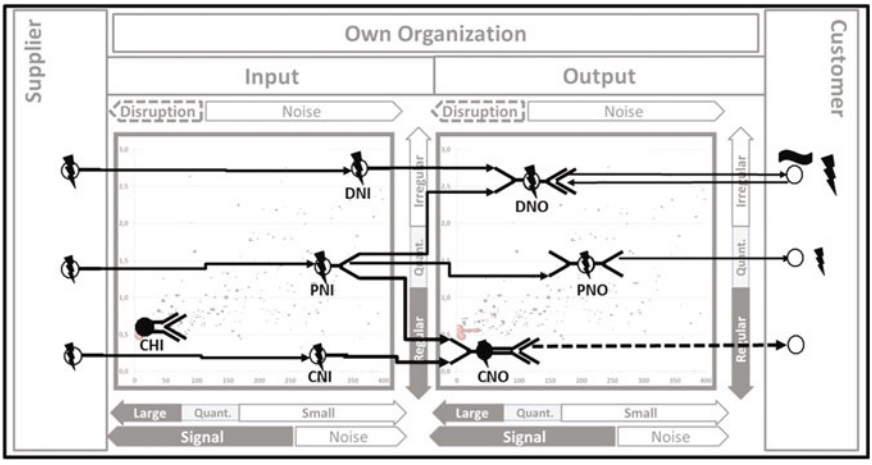

Fig. 4.8 Cascading failure in strongly linked organization

Perturbation absorption by inventories is the most widespread and well-known approach to create a so-called escape window in the network against painful demand fluctuations and perturbations (Csermely 2009). The methodology has wide array of literature, one of the most advanced scientific approaches is available in the monograph of Snyder and Shen (2011).

Perturbation absorption by alternative in-links is feasible and often used both for protecting a source node or an in-link of sink node. In the case of a source node a typical solution is to have more than one supplier (dual- or multisourcing). In the case of a sink node, the mandatory transversal sync requires all resources to be at the right place, at the right time and in right quality for production/conversion. Therefore, alternative in-links are created often by utilizing multiskilled men/operators and using identical or similar (multipurpose) machines. Multiskilled operators and similar machines create adaptability increasing degenerative redundancy, similar to those that Csermely described in other living networks (Csermely 2009).

Perturbation absorption by creative element in DSN's organization was designed and successfully implemented by one of the authors in 2006 but called it differently. The creative element was defined and generalized by Csermely (2008). Creative elements in protein, cellular and social networks are active centres in the network with free energy (hot spots) and help the network to survive unprecedented challenges, offering alternative pathways and dissipating the perturbation (Fig. 4.9).

Creative elements in DSN (CRE) can be built from sink-dating-hubs (finished product with a large number of weak out-links in weak transversal sync) combined with Network-Based Red-Amber-Green Kanban, i.e. free energy for the meta-level (for the organization), which is cumulated in the amber inventory. CRE must have several common sources with Disruptive Node-Out (DNO) and with the to-be-protected Priority Nodes-Out (PNO). When a disruptive demand signal enters

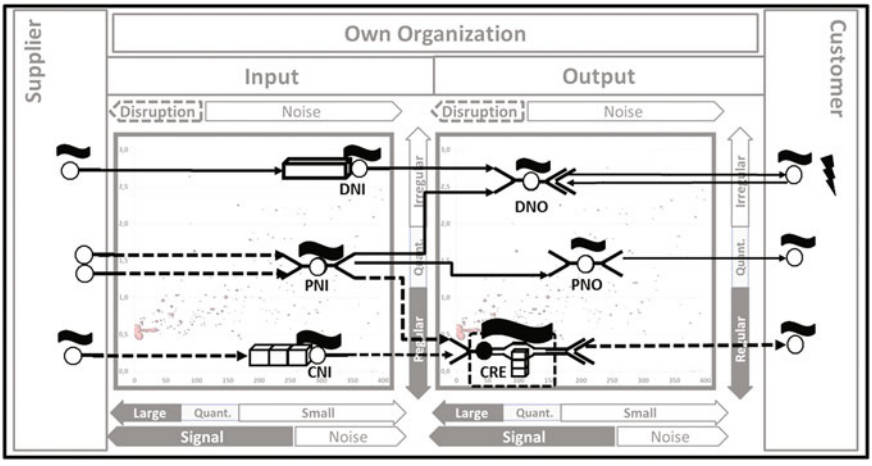

Fig. 4.9 Creating weak links and perturbation traps in organization

the resource paths are rearranged, giving the extra supply of common sources to disruptive sink/node and other high priority sinks/nodes, all the while CRE can survive without commonly used sources for a certain extended period. This creates adaptive flexibility in our organization and so we can eliminate/reduce the probability of cascading failures.

4.6 Conclusion

We highlighted the characteristic structural patterns of the demand-supply network (DSN) at different hierarchical levels with different granularity. We have matched the supply chain terms with the network science ones for creating the bridge between those two disciplines. The investigated structural patterns often can explain why our well-known and proven supply chain heuristics work in one case and are ineffective in other cases. We have shown how to create adaptive flexibility in our organization adding to proven heuristics a network-based solution, the 'creative element'.

The worked out methodology based on CQIG helps in identifying the organization's network skeleton. The latter defines the critical nodes we have to deal with to minimize the risk of cascading failures and to mitigate their impact in our organization. The Combined Quantity Irregularity Graphs are effective in smaller organizations where the number of nodes is just a few hundred or a thousand.

Further advancement will be a solution for larger organizations with thousands of nodes where we have developed the matrix representation of an organization and its environment. That is an upper triangle quadratic matrix with rectangular blocks of bipartite adjacent echelon-pairs. The relevant matrix algebraic operations are under development and are subject to further publications.

Kazemian and Aref have incorporated in their novel stochastic mathematical optimization model the effect of the different types of bottlenecks. Those differentiating bottlenecks in their flexible supply chain network design enabled a considerably better optimization (Kazemian and Aref 2016). The differentiating aspects resulting from the different connectedness of the supply chain network's nodes—in-degree, out-degree, between centrality—and of characteristic motives (e.g. shown in Fig. 4.8) may open up new methods in stochastic mathematical optimization modelling.

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Chapter 5
Knowledge Management for Flexible and Entrepreneurial Organization

Sumant Kumar Bishwas

5.1 Introduction

One of the major challenges in the current knowledge era is to manage the rapid environmental changes, specially the quick changing customer demands (Valle et al. 2011). Success of organization depends on the degree to which the organization can manage the environmental uncertainty and changes (Folami and Powers 2009). In the current knowledge era, knowledge has been acknowledged as one of the organizational strategic assets which is critical for organizational success or failure and has been defined as the lifeblood of the organization (Eibl and Schwenk 2009). Theory of knowledge creation describes organization knowledge into two types; tacit, and explicit (Nonaka and Takeuchi 1995). Knowledge based view states that knowledge is one of the major strategic resource which is infinite in nature as compare to the tangible resources that are limited (Hamel 1998; McElroy 2000).

Concept of knowledge management has been shifted from the way it was explained initially. Current focus is more on integration of the knowledge management process with other organizational processes rather than considering it in an isolated manner. Marjanovic and Freeze (2012) findings have strengthened this view that linking other processes with knowledge management will contribute to high performance. A proper fit should be maintained between the organization and its changing environment (Eppink 1978). Flexibility is the need of the hour to deal with these changes and to remain ahead in the competition. More environmental uncertainty demands more concern for the flexibility issue. Dreyer and Gronhaug (2004) have defined flexibility as an important organizational resource. Organizations which incorporate concept of flexibility can accommodate the changes in a better way than others.

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Similar to flexibility, another crucial aspect is to develop entrepreneurial orientation. It is acknowledged as important aspect for organization to survive and perform in a continuous manner (Chen et al. 2005). Similar findings were given by Omerzel and Antoncic (2008) that having knowledge of entrepreneurship is a critical thing for organizational survival.

Although it is clear from the literature that strategic knowledge management, flexibility and entrepreneurship are critical issues for organization but there is still lack of any specific framework that explains the relationships between these processes. This study is an attempt to fill this gap, and to suggest a framework that will explain the interrelationships between strategic knowledge management, flexibility, and entrepreneurship. This chapter highlights the importance of knowledge management process (strategic perspective) for developing a flexible, entrepreneurial orientation in the organization.

5.2 Methodology

This study has been done using empirical survey research. A questionnaire has been developed using the research variables reflected in literature for strategic knowledge management and entrepreneurship. Factor analysis and reliability testing have been conducted to finalize the factors of strategic knowledge management and entrepreneurship using 78 samples (inputs) from diverse area experts that includes academicians, industry people, government policy makers, etc. The factors of flexibility have been taken from existing literature (Bishwas 2015). For the main survey, data has been collected from IT and Automobile industries' experts using non-probability sampling techniques like convenience, judgmental, and snowball sampling. e-mail surveys and personal interactions have been used for the data collection. Total 225 sample responses have been collected that consists 116 responses from IT industry and 109 responses from automobile industry. Univariate, correlation, and regression analysis have been used to explain the interrelationships between knowledge management, flexibility and entrepreneurship, and to develop the final framework. SPSS 20 has been used for the analysis.

5.3 Knowledge Management, Flexibility and Entrepreneurship

To remain competitive and vital for longer-term, organizations are required to maintain a balance between its change and stability processes (Adler 1988; Volberda 1996). Integrating flexibility with other processes help to develop a supportive environment and capability to manage the changes, and can convert the situation into opportunity for the organization.

Flexibility can be seen as a means to increase control in a highly unstable environment, and can be used as a tool to deal with the uncertain environment (Volberda 1997). It has been defined as one of the vital organizational aspects which is linked with other processes like learning, innovation, etc. (Sushil 2004; 2013a, b). Changing customer demands can be managed in a better way by adopting a flexible approach. Flexibility reflects the ability to develop new products as par the changing requirement and about the strategic issues like planning to enter into new markets (Volberda 1998).

Labour flexibility is one kind of flexibility that is a matter of concern to manage the uncertainty and changes in terms of economical, technological and cultural perspectives (Looise et al. 1998). Importance of labour flexibility issues in the organization has been reflected by Singh and Chauhan (2013) in their study on lean manufacturing process. Strategic flexibility is another type of flexibility that is very crucial and not easily achievable by organizations (Sushil 2014). Incorporation of strategic flexibility can be seen as the capability of managers deployed to face the environmental uncertainty in terms of realizing the consequences and responding in a quick manner (Volberda 1996). Further, Sumita and Yoshii (2013) have discussed about the significance of strategic flexibility for managing the diverse and changing customer demands in matured market economies.

Entrepreneurial knowledge has been defined as another crucial aspect for organizational survival (Omerzel and Antoncic 2008). Flexibility should be integrated at various levels and with various processes in the organization rather than considering it in an isolated manner (Sushil 2001, 2013a, b). Importance of integration of flexibility with entrepreneurship has been suggested as one of the key facets for future competition (Bhardwaj and Momaya 2006). Entrepreneurs exploit opportunities (inputs) and create new ventures (outputs) through managing the resources with an entrepreneurial mindset (Vincenzo et al. 2007). It has been considered a critical issue for survival and performance (Barringer and Bluedorn 1999).

Higher degree of available entrepreneurial skills increases the possibility of innovation, development, and growth in the organization (Michelacci 2003). People with entrepreneurial orientation develop competencies, skills, and practices continuously, acquire required knowledge for future growth, and create novel opportunities in their industries. The decisions taken by entrepreneurs are one of the important deciding factors to decide about where and how to grow and boost up the growth path for organization (Carsrud and Brannback 2011). According to Isaac et al. (2009), trust between members and entrepreneurs, and decision-making in a participative way contribute towards a healthy organization culture.

The interrelationships between entrepreneurship and flexibility have been discussed by Sushil (2004, 2013a, b). The author has explained that higher degree of flexibility in the organization stimulates entrepreneurship. Organization can achieve high growth through its technical infrastructure, knowledge, organizational flexibility and entrepreneurship (Guadamillas et al. 2008). According to Lee et al. (2012), organization supportive culture, top management support, and knowledge

Table 5.1 Strategic knowledge management variables with supporting literature

Variables	Literature support
Knowledge audit	Carneiro (2000), Call (2005), Akhavan et al. (2006), Vuuren and Jansen (2008)
Knowledge strategy	Donogue et al. (1999), KPMG Report (2000), Singh et al. (2006), Akhavan et al. (2006), Wang and Belardo (2009), Zack et al. (2009)
Top management support	Davenport et al. (1998), Liebowitz (1999), Ribière and Khorramshahgol (2004), Akhavan et al. (2006), Batra (2010)
Mutual trust	Call (2005), Akhavan et al. (2006), Spender (2006)
Knowledge sharing	Ribière and Khorramshahgol (2004), Chermin and Nijhof (2005), Batra (2010), Mustafa et al. (2016)
Knowledge infrastructure	Stonehouse et al. (2001), Davenport (2005), Spender (2006), Sing et al. (2006), Wang and Belardo (2009), Fatt and Khin (2010), Aliei and Bahrololoum (2011)

infrastructure are some of the issues that play a major role in success of knowledge management process.

Research variables have been identified for strategic knowledge management and entrepreneurship process that are reported in Tables 5.1 and 5.2. Strategic flexibility, adaptive capacity of leadership, and labour flexibility have been selected as research variables for flexibility process (Bishwas 2015). The factors for strategic knowledge management and entrepreneurship have been finalized using factor analysis. Total 78 samples have been collected for the factor analysis using judgmental and convenience sampling methods. The respondents represent diverse areas of expertise like from government policy makers, academicians, industry experts, etc.

5.4 Results and Discussion

SPSS 20 has been used for the analysis purpose. Factor analysis, univariate and regression analysis have been used to finalize the factors, understand the importance of these processes, and to explain the interrelationships of strategic knowledge management with flexibility and entrepreneurship. Finally, the integrated framework has been developed using the regression models summary.

5.4.1 Factor Analysis

Factor analysis results for strategic knowledge management and entrepreneurship have been shown in Tables 5.3 and 5.4. The factor loadings greater than 0.5 (ranges from 0.538 to 0.877) has been considered as the minimum value for factor finalization, where the Cronbach alpha value ranges between 0.592 and 0.841.

Table 5.2 Entrepreneurship variables with supporting literature

Variables	Literature support
Proactiveness	Morris et al. (1994), Sonfield and Lussier (1997), Heilbrunn (2008), Lau et al. (2010)
Risk taking orientation	Morris et al. (1994), Sonfield and Lussier (1997), Guadamillas et al. (2008), Heilbrunn (2008), Molina and Callahan (2009)
Entrepreneurial intensity	Morris et al. (1994), Topol (1996), Heilbrunn (2008)

As shown in Table 5.3, factor analysis suggested six factors for strategic knowledge management process. In the exploratory phase of this study also, six dimensions have been identified from literature to measure the strategic knowledge management process. Out of the 23 items chosen initially, two items have been dropped after factor analysis. The slight difference that has been reflected in the factor analysis results is that mutual trust and sharing have emerged as one single factor, while knowledge management strategy factor has split into two factors; knowledge management strategy formulation, and knowledge management strategy execution. Knowledge audit factor has been rephrased to 'knowledge awareness'.

Table 5.5 provides the details of the respondents used for main survey.

From Table 5.5, it can be seen that the respondents are having vast experience (average > 10 year), mostly the respondents are male, having master's degree, and nearly 50% were involved in knowledge management process. Table 5.6 summarizes the outcome of the univariate analysis.

As apparent from the statistics given in Table 5.6, the most significant factors for strategic knowledge management have emerged as knowledge infrastructure (SKM1), mutual trust and sharing (SKM2), top management support (SKM5), and knowledge management strategy formation (SKM6). Similarly, flexible resource usage (VPF2) and adaptive capacity of leadership (VPF3) factors of flexibility, proactiveness (VPE1) factor of entrepreneurship have emerged as the important concerning factors for the organizations.

5.4.2 Regression Analysis

To find the interrelationships between strategic knowledge management factors with flexibility and entrepreneurship, step-wise regression has been used. The first regression model has been developed using flexibility as dependent variable and the strategic knowledge management factors as independent variables. Results suggest that mutual trust and sharing (SKM2), knowledge awareness (SKM3), and knowledge management strategy formation (SKM6) are the three most significant factors that affect flexibility in the organization. The R Square value of 0.530 in Table 5.7(a) indicates that these three factors account for 53% variation in

Table 5.3 Factor analysis of strategic knowledge management

Macro variable	Micro variables	Factor loadings	Cronbach alpha	KMO	Sign	Cum % of loadings	Items confirmed (items dropped)
Strategic knowledge management	Knowledge infrastructure-1	0.687					
	Knowledge infrastructure-1	0.777					
	Knowledge infrastructure-1	0.656	0.841				
	Knowledge infrastructure-1	0.702					
	Knowledge infrastructure-1	0.747					
	Mutual trust and sharing-2	0.717					
	Mutual trust and sharing-2	0.725	0.807				
	Mutual trust and sharing-2	0.747					
	Mutual trust and sharing-2	0.538					
	Knowledge awareness-3	0.548					
	Knowledge awareness-3	0.797	0.766				
	Knowledge awareness-3	0.748					
	Knowledge awareness-3	0.566					
	Knowledge management strategy (KMS) execution-4	0.760	0.753	0.780	0.000	69.321	21 (2)
	KMS execution-4	0.721					
	KMS execution-4	0.726					
	Top management support-5	0.729					
	Top management support-5	0.857	0.716				
	Top management support-5	0.560					
	KMS formation-6	0.745	0.592				
	KMS formation-6	0.649					

Table 5.4 Factor analysis of entrepreneurship processes

Macro variable	Micro variables	Factor loadings	Cronbach alpha	KMO	Sign	Cum % of loadings	Item confirmed (item dropped)
Entrepreneurship	Proactiveness-1	0.789					
	Proactiveness-1	0.776	0.838				
	Proactiveness-1	0.826					
	Risk taking orientation-2	0.783	0.828	0.842	0.000	75.888	9 (0)
	Risk taking orientation-2	0.778					
	Risk taking orientation-2	0.746					
	Entrepreneurial intensity-3	0.547	0.786				
	Entrepreneurial intensity-3	0.877					
	Entrepreneurial intensity-3	0.827					

Table 5.5 Respondents profile for main survey (organization type, respondents details)

Industry (total 225)	IT		Automobile	
	116 (51.55%)		109 (48.45%)	
Average work experience	Total	Within current organization		Involvement in KM
	10.75 year	6.47 year		110 out of 225 (48.88%)
Gender		Education		
Male	Female	Graduate	Masters	Doctorate
198 (88%)	27 (12%)	69 (30.66%)	142 (63.11%)	14 (6.22%)

flexibility process in the organization. The ANOVA values for the regression model are shown in Table 5.7(b), which indicate validation at 99% confidence level. The coefficient summary, as shown in Table 5.7(c), reflects high regression coefficient (β value) of mutual trust and sharing.

Similar to the first model, the second regression has been done considering entrepreneurship as dependent variable and all the strategic knowledge management factors as independent variables. The results from second model reflect that mutual trust and sharing (SKM2), and knowledge management strategy execution (SKM4) are the two critical factors of knowledge management that effect entrepreneurship in the organization. The R Square value of 0.446 in Table 5.8(a) signifies that these two factors explain 44.60% variation of entrepreneurship. ANOVA values have been presented in Table 5.8(b) that indicates validation at 99% confidence level. Coefficient summary presented in Table 5.8(c), shows higher regression coefficient

Table 5.6 Univariate analysis of micro variables (N = 225)

	Macro variable code	Mean	Median	Mode	Std. deviation	Variance	Minimum	Maximum
Strategic knowledge management	SKM1	3.926	4.000	3.600	0.755	0.569	1.00	5.00
	SKM2	3.527	3.750	4.000	0.826	0.682	1.00	5.00
	SKM3	3.314	3.500	3.500	0.689	0.475	1.00	5.00
	SKM4	3.369	3.667	3.670	0.854	0.729	1.00	5.00
	SKM5	3.820	4.000	4.000	0.786	0.617	1.00	5.00
	SKM6	3.978	4.000	4.000	0.756	0.571	1.00	5.00
	VPF1	3.484	3.667	4.000	0.870	0.758	1.00	5.00
Flexibility	VPF2	3.588	3.750	4.000	0.877	0.768	1.00	5.00
	VPF3	3.505	3.500	4.000	0.844	0.712	1.00	5.00
Entrepreneurship	VPE1	3.561	3.667	4.000	0.880	0.774	1.00	5.00
	VPE2	3.285	3.333	3.330	0.798	0.637	1.00	5.00
	VPE3	3.143	3.000	3.000	0.863	0.744	1.00	5.00

Table 5.7 Regression results_Strategic knowledge management factors_independent and Flexibility as dependend variable

(a) Regression analysis_flexibility as dependent variable

Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate
1	0.687[a]	0.472	0.470	0.57661
2	0.716[b]	0.513	0.509	0.55504
2	0.728[c]	0.530	0.523	0.54694

(b) ANOVA_flexibility as dependent variable

Model		Sum of squares	*Df*	Mean square	*F*	Sig.
1	Regression	66.367	1	66.367	199.613	0.000[b]
	Residual	74.143	223	0.332		
	Total	140.510	224			
	Regression	72.120	2	36.060	117.053	0.000[c]
	Residual	68.391	222	0.308		
	Total	140.510	224			
	Regression	74.401	3	24.800	82.905	0.000[d]
	Residual	66.110	221	0.299		
	Total	140.510	224			

(c) Coefficient summary_flexibility as dependent variable

Model		Unstandardized coefficients		Standardized coefficients	*t*	Sig.
		B	Std. error	Beta		
1	(Constant)	1.211	0.169		7.168	0.000
	SKM2	0.659	0.047	0.687	14.128	0.000
2	(Constant)	0.770	0.192		4.014	0.000
	SKM2	0.505	0.057	0.526	8.789	0.000
	SKM3	0.297	0.069	0.259	4.321	0.000
3	(Constant)	0.454	0.221		2.056	0.041
	SKM2	0.484	0.057	0.505	8.489	0.000
	SKM3	0.228	0.072	0.198	3.155	0.002
	SKM6	0.155	0.056	0.148	2.761	0.006

Dependent variable: VPF_T
[a]Predictors: (constant), SKM2
[b]Predictors: (constant), SKM2, SKM3
[c]Predictors: (constant), SKM2, SKM3, SKM6
[d]Dependent variable: VPF_T

(β value) both for mutual trust and sharing, and knowledge management strategy execution.

The regression analysis models have been summarized in Fig. 5.1.

The framework shown in Fig. 5.1 suggests that strategic knowledge management factors have significant effect on flexibility and entrepreneurship in the

Table 5.8 Regression results_Strategic knowledge management factors_independent and Entrepreneurship as dependend variable

(a) Regression analysis model_entrepreneurship as dependent variable

Model	*R*	*R* square	Adjusted *R* square	Std. error of the estimate
1	0.586[a]	0.343	0.340	0.61526
2	0.668[b]	0.446	0.441	0.56613

(b) ANOVA_entrepreneurship as dependent variable

Model		Sum of squares	*Df*	Mean square	*F*	Sig.
1	Regression	44.108	1	44.108	116.522	0.000[b]
	Residual	84.415	223	0.379		
	Total	128.523	224			
2	Regression	57.370	2	28.685	89.498	0.000[c]
	Residual	71.153	222	0.321		
	Total	128.523	224			

(c) Coefficient summary_entrepreneurship as dependent variable

Model		Unstandardized coefficients		Standardized coefficients	*t*	Sig.
		B	Std. error	Beta		
1	(Constant)	1.435	0.180		7.959	0.000
	SKM2	0.537	0.050	0.586	10.795	0.000
2	(Constant)	0.928	0.184		5.055	0.000
	SKM2	0.366	0.053	0.399	6.906	0.000
	SKM4	0.330	0.051	0.372	6.433	0.000

Dependent variable: VPE_T
[a]Predictors: (constant), SKM2
[b]Predictors: (constant), SKM2, SKM4
[c]Dependent variable: VPE_T

organization. Mutual trust and sharing (SKM2) has emerged as the most important factor followed by knowledge awareness (SKM3) and knowledge management strategy formation (SKM6) that effect the flexibility process. Similarly, mutual trust and sharing (SKM2) is again emerging as the most critical factor followed by knowledge management strategy execution (SKM4) that effect entrepreneurship. The results strengthen the findings of Mustafa et al. (2016) which found that knowledge sharing of middle management in the organization improve the corporate entrepreneurship.

The final framework (Fig. 5.1) reflect that in a complete manner, strategic knowledge management can be seen as one of the important process that can lead to flexibility and entrepreneurship.

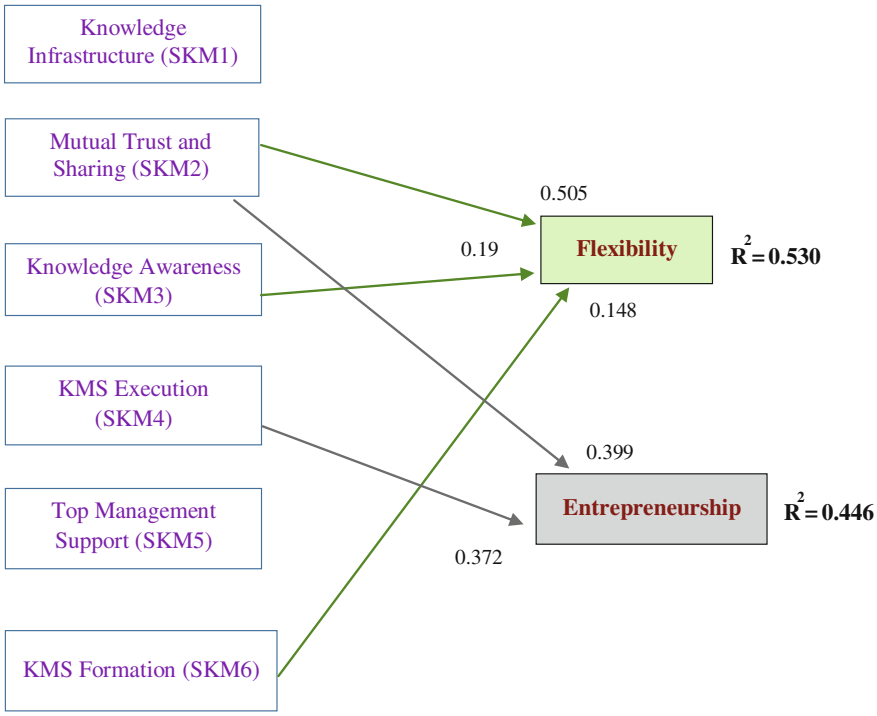

Fig. 5.1 Summary of regression models of knowledge management with flexibility and entrepreneurship

5.5 Conclusion

Knowledge is one of the vital strategic assets for organization that helps to remain ahead in the competition. Flexibility and entrepreneurship are the two critical processes that play a crucial role in the organization to manage the changes faster than others. Developing flexibility and entrepreneurship in the organization is defined as one of the critical concern where knowledge management process can be seen as a strategic tool. Mutual trust and sharing, knowledge awareness, and knowledge management strategy (formation as well as execution) are some of the critical aspects of knowledge management that may help in achieving the objectives to become a flexible and entrepreneurial organization.

Appendix

Questionnaire Template

PART ONE

Please rate the statements given below **on a scale of 5**, where

1 = you **Strongly Disagree (SD)** with the statement.
2 = you **Disagree (D)** with the statement.
3 = you **Neither Agree nor Disagree (N)** with the statement. You are neutral.
4 = you **Agree (A)** with the statement.
5 = you **Strongly Agree (SA)** with the statement.

Knowledge Management

Statements	Response				
	SD (1)	D (2)	N (3)	A (4)	SA (5)
Top management is aware about the importance of knowledge management process.	☐	☐	☐	☐	☐
Management is committed for knowledge management projects in the organization.	☐	☐	☐	☐	☐
Sufficient Budget has been allotted for knowledge management projects.	☐	☐	☐	☐	☐
Top management always encourages other members to participate in sharing their views about knowledge management process.	☐	☐	☐	☐	☐
Organization is aware about the existing available knowledge.	☐	☐	☐	☐	☐
There is no redundant (same information repeated) information in the system.	☐	☐	☐	☐	☐
Organization is well aware about the knowledge gap i.e. what kind of knowledge is missing in the organization.	☐	☐	☐	☐	☐
Knowledge resources and capability play an important role in strategy planning process.	☐	☐	☐	☐	☐
Knowledge strategy is properly aligned with business strategy.	☐	☐	☐	☐	☐
Targets are being set for knowledge management projects.	☐	☐	☐	☐	☐
Organization focuses on the technical infrastructure development for implantation of knowledge management.	☐	☐	☐	☐	☐
Organizational members understand each others values and feelings.	☐	☐	☐	☐	☐
Employees have trust on management.	☐	☐	☐	☐	☐
Management has a trust on its employees.	☐	☐	☐	☐	☐
Effective communication is encouraged among employees.	☐	☐	☐	☐	☐
People are rewarded for their contribution in knowledge sharing process.	☐	☐	☐	☐	☐
The knowledge repository is easily accessible/reachable to the members.	☐	☐	☐	☐	☐
The organization is having sufficient IT capability, i.e. Technical infrastructure like internet, intranet, e-mail systems, database etc.	☐	☐	☐	☐	☐
The information systems are user friendly in nature (easily understandable to the organizational members).	☐	☐	☐	☐	☐
Available IT systems efficiently support the storage and retrieval of knowledge.	☐	☐	☐	☐	☐
People use e-mail and intranet for a larger extent of formal communication in the organization.	☐	☐	☐	☐	☐

Entrepreneurship	Response				
	SD (1)	D (2)	N (3)	A (4)	SA (5)
Organization always looks for developing new opportunities.	☐	☐	☐	☐	☐
Response to the changes in a proactive way (before it occurs).	☐	☐	☐	☐	☐
Proper planning is given more importance in the organization.	☐	☐	☐	☐	☐
People are willing to take risk.	☐	☐	☐	☐	☐
Organization is having the knowledge of external environment like market condition, competitor etc.	☐	☐	☐	☐	☐
Organizational culture encourages people to take risk.	☐	☐	☐	☐	☐
Organization has a large number of entrepreneurial events/activities.	☐	☐	☐	☐	☐
Most of the entrepreneurial decisions are risky in nature.	☐	☐	☐	☐	☐
The decisions taken are usually in the nature of complete new innovation oriented.	☐	☐	☐	☐	☐

PART TWO – DEMOGRAPHIC DETAILS OF THE RESPONDENT

Name (optional) : _____

Organization Name (Optional) : _____ Public / Private

Designation: _____ Industry/Sector _____

Gender : Male / Female

Highest Qualification : _____

Total work experience (number of years) : _____

Experience in current company (number of years) : _____

Are you directly involved in Knowledge Management Process : Yes / No

Email id (Optional):

**********Thank You**********

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Chapter 6
Managing Workplace Diversity Through Organizational Climate

Umesh K. Bamel, Happy Paul and Nisha Bamel

6.1 Introduction

Research has suggested that workforce diversity widens the knowledge and experience pool of organizations (Williams and O'Reilly 1998; Brickson 2000). To balance the mounting multiplicity of business, i.e. multi-location presence, multiple stakeholders, multi-product portfolios, etc. organizations are consciously striving to achieve workforce diversity. Therefore, in recent times, workforce diversity has become one of the major concerns of the organizations (Thomas and Clark 2003; Evans 2012; Bamel et al. 2016), and the field of diversity research has developed to include a variety of phenomenon to its ambit (Jackson et al. 2003; Bamel et al. 2014). Demographic diversity is one such significant phenomenon which is an inherent element of the society and that of the organizations. It is suggested that workforce diversity is more likely to generate positive results (Williams and O'Reilly 1998; Brickson 2000); however, contrarily the demographic anomalies are also believed to cause inconsistencies in behavioural dynamics (Hoffman and Maier 1961 cited in Hyung and John 2012; Bamel et al. 2015). Owing to this reason the workforce diversity is quite often referred as a double edge sword (Deshwal and Choudhary 2012; van Dijk et al. 2012) and very frequently counted among the significant business challenges. By and large workforce diversity may be

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understood as the degree to which group members' attributes vary both subjectively and objectively (van Knippenberg et al. 2007). The continuum of these attributes is very wide and includes the attributes that are easily noticeable (age, gender, ethnicity and racial), attributes that could be identified with little attention (education, tenure and job hierarchy), and the attributes that could be identified only after a close consideration of the subject of interest (knowledge, values, personality and skills).

Literature (Tsui et al. 1992; Schreiber 1979; Plaut 2010; Bell et al. 2011) has substantiated the fact that previously mentioned attributes certainly leads to behavioural variations at work place. Much of the diversity related research focused on a relationship of underlying processes between workforce diversity and behavioural consequences. Like, van Dijk et al. (2012) narrated the consequential effect of workforce diversity on team and organizational effectiveness. Jackson et al. (2003) also noted that nearly 75% of the diversity studies examined the association of demographic diversity performance. Therefore, we also assume the conventional wisdom that workforce diversity functions on performance. However, these consequences and interaction depends on the construction and composition of workforce diversity. This means that the interactionist mechanism will be a decisive factor to determine whether the effect of demographic diversity on individual or organizational outcomes would be positive or negative. For this, we propose an intervention to the subjective mechanism so as to increase the chances of getting positive outcomes. We suggest that organizational climate (OC) will moderate the diversity-workplace outcomes relationship.

OC is defined as shared value, beliefs and work environment that could intervene or interact with and could have impact on the employee behaviours (Long 2000). In a meta-analytic review of diversity related reports Jackson et al. (2003) argued that the consequences of workforce diversity cannot be contained to minimal. Though they agreed that in presence of certain organizational constructs, moderation in diversity consequences could be attainable. However, little is known about the mechanism of organizational climate on managing demographic diversity. Therefore, in the present study we sought to answer this question and a mix of individual (age and gender) and relational (education, managerial level occupied) attributes have been considered as component of demographic diversity.

6.2 Organizational Climate for Workforce Diversity

Due to its sociological orientation, the concept of OC has gained appropriate attention of both the scholar and practitioner community (Dickson et al. 2006; James et al. 2008). Guion (1973) refers OC as an "attribute or set of attributes that differ from organization to organization and can be described, measured and classified". It may be considered as a personality of an organization as it is the sum

of the organizational structure, policies, practices, processes and other organizational activities. Kopelman et al. (1990) defined OC as "psychologically meaningful descriptions of contingencies and situational influences that individuals use to apprehend orders, predict outcomes and gauge the appropriateness of their organizational behaviours". Schneider et al. (1992) has added the socio-psychological element in the concept and defined OC as 'employees' perceptions of the events, practices and procedures as well as their perceptions of the behaviours that are rewarded, supported and desired within an organization.

OC is an explicit form for managing demographic diversity and obviously it differs from other OC constructs; however, it is an established fact that the general organizational climate provides a platform to nurture this specific form of climate. Information dissemination is an important building block of behaviour as individual receives information about environmental attributes through senses (sensory impressions), this information proceeds to next stage of cognitive process where subjective valuation of the received information is done, the subjective valuation of the environmental attributes lead to attitude development, and the attitude often reflects in behaviour (although not always). Therefore, the OC for diversity constructs ought to encompass those organizational activities which have a direct impinged on the discussed information dissemination process. The list may include few which are considered in present study, i.e. organizational processes; perceive fairness in rewards allocation; information sharing process; and interpersonal relationships and altruistic behaviour. Though it is not an exhaustive set of variables and could be extended further. However, present study is limited to these dimensions of the OC and demonstrates that these dimensions could be perceived equally by employees of the organizations so as to ensure the positive effect on the individual and the organizational outcomes.

6.3 Methodology

As suggested by Bailey (1978) a cross-sectional research design was used to collect the primary data within a short period of time and less expensively. The responses were collected from executive/managerial level of employees of Indian organizations both public and private located mainly in northern region of the country. Snowball sampling technique was used to obtain the information. A survey questionnaire was administered personally as well as through electronic mails. The first part of the questionnaire included the questions regarding demographic attributes (age, gender, managerial level and education). The second part included the questions on the perception of respondents regarding OC. To quantify the OC perception of participants, statements were taken from the metric of Pethe et al. (2001). A total of twenty-one statements were taken representing the four factors, i.e. organizational processes (six items), perceived fairness in reward allocation

(five items), information sharing (four items), and interpersonal relationship and altruistic behaviour (six statements). The respondents were asked to record their responses on a seven point Likert scale (1—strongly disagree to 7—strongly agree). The reliability coefficient (Cronbach alpha) of the OC measure was found to be 0.902. Finally, a sample size of 271 respondents was chosen.

6.4 Analysis and Results

Statistical analysis of data was undertaken using the SPSS 17.0. For the present study, analysis was carried out at two sectoral levels, i.e. public and private. Initially, descriptive statistics were employed to obtain an overall representation of sample. It was used to calculate means, standard deviations, frequencies and percentages to examine the individual sets of demographic variables measuring organizational climate. Reliabilities of the measures were evaluated using Cronbach's alpha coefficients. Further, factorial univariate analysis of variance (UNIANOVA) was used to analyze the effect of demographics on OC measure and to check whether or not the respondents' perception varies significantly across various levels of demographic variables. For this purpose, demographic attributes (age, gender, managerial levels and education) were treated as independent variables whereas OC measure was treated as dependent variable.

6.4.1 Descriptive Statistics

Of the total 271 respondents, 37.2% (n = 101) were from public sector organizations and 62.8% (n = 170) were from private organizations. The average age of the respondents was 34. Demographic characteristics of the sample are shown in Table 6.1.

6.4.2 Univariate Analysis of Variance

The results of univariate analysis of variance are reported in Tables 6.2 and 6.3 for the private and public organizations, respectively. The main effects of our demographic variables on OC perception is of much interest in context to this study because the objective is only to ascertain the plausibility of having an equal perception of climate among the organizational members. To get deeper insights the

Table 6.1 Demographic characteristics of the sample

Org. type	Characteristic (n = 271)	Frequency (%)	OC mean	SD
Public	*Age*			
	Below 35 years	33 (12.1)	4.77	0.750
	35–45 years	25 (9.2)	4.71	0.758
	Above 45 years	43 (15.8)	4.71	0.815
	Gender			
	Female	15 (5.5)	4.76	0.718
	Male	86 (31.7)	4.72	0.786
	Level of education			
	Graduation or below	66 (24.3)	4.79	0.799
	Post-graduation or above	35 (12.9)	4.61	0.718
	Managerial level			
	Junior	29 (10.7)	4.79	0.735
	Middle	27 (9.9)	4.78	0.812
	Senior	45 (16.6)	4.66	0.785
Private	*Age*			
	Below 35 years	93 (34.3)	4.87	0.701
	35–45 years	54 (19.9)	5.00	0.832
	Above 45 years	23 (8.4)	4.86	0.532
	Gender			
	Female	16 (5.9)	5.02	0.708
	Male	154 (56.8)	4.90	0.728
	Level of education			
	Graduation or below	75 (27.6)	5.01	0.747
	Post-graduation or above	95 (35.0)	4.83	0.701
	Managerial level			
	Junior	93 (34.3)	4.92	0.688
	Middle	53 (19.5)	4.92	0.833
	Senior	24 (8.8)	4.86	0.633

Source Primary data

analysis was carried out at two sectoral levels for type of organization. This gave us a clear picture of both public and private sector.

The results for private organizations show that all the main effects are non-significant which indicate that the employees of the private organizations perceived OC equally. However, GENDER x M_LEVEL interaction effect is significant ($F = 4.154$, $p = 0.043$). This suggests that the effect of gender depends on the managerial level. Similarly, the results for public organizations show that all the

Table 6.2 Tests of between-subjects effects for private organizations

Source	Type III sum of squares	*df*	Mean square	*F*	Sig.
Corrected model	5430.49	19	285.816	1.268	0.213
Intercept	230885.156	1	230885.156	1024.230	0.000
Age	396.79	2	198.396	0.880	0.417
Gender	2.20	1	2.202	0.010	0.921
Education	13.61	1	13.612	0.060	0.806
Work ex.	35.82	2	17.912	0.079	0.924
Age * gender	14.44	1	14.466	0.064	0.800
Age * educa	188.27	2	94.135	0.418	0.659
Age * workex	85.75	3	28.581	0.127	0.944
Gender * educa	14.94	1	14.904	0.066	0.797
Gender * workex	936.44	1	936.440	4.154	0.043
Educa * workex	218.20	2	109.100	0.484	0.617
Age * gender * educa	0.00	0			
Age * gender * workex	303.98	1	303.977	1.348	0.247
Age * educa * workex	1074.32	1	1074.325	4.766	0.031
Gender * educa * workex	0.000	0			
Age * gender * educa * workex	0.000	0			
Error	33813.48	150	225.423		
Total	1849372.00	170			
Corrected total	39243.98	169			

Source Primary data; dependent variable: OC; R square = 0.138 (adjusted R square = 0.029)

main effects are nonsignificant which indicate that the employees of public organizations also perceived OC equally. However, EDUCATION x M_LEVEL interaction effect is significant ($F = 5.292$, $p = 0.024$). This suggests that the effect of education depends on the managerial level. The results, thus demonstrate that it is possible that employees perceive OC equally irrespective of the type of organization. The only significant result was in relation to the managerial level as its interaction with education and gender. This may not be an issue because the overall interaction effect of all the demographic variables was found to be nonsignificant. Since, all the demographic variables operate in conjunction, thus, it may be interpreted that the climate of an organization can be perceived equally.

Table 6.3 Tests of between-subjects effects for public organizations

Source	Type III sum of squares	*df*	Mean square	*F*	Sig.
Corrected model	4432.893	15	295.526	1.143	0.332
Intercept	300660.923	1	300660.923	1162.826	0.000
Age	1389.497	2	694.749	2.687	0.074
Gender	4.699	1	4.699	0.018	0.893
Education	79.489	1	79.489	0.307	0.581
Work ex.	1383.775	2	691.888	2.676	0.075
Age * gender	0.000	0			
Age * educa	1010.940	1	1010.940	3.910	0.051
Age * workex	263.598	1	263.598	1.019	0.316
Gender * educa	7.838	1	7.838	0.030	0.862
Gender * workex	0.000	0			
Educa * workex	1368.320	1	1368.320	5.292	0.024
Age * gender * educa	0.000	0			
Age * gender * workex	0.000	0			
Age * educa * workex	0.000	0			
Gender * educa * workex	0.000	0			
Age * gender * educa * workex	0.000	0			
Error	21977.642	85	258.560		
Total	1024645.000	101			
Corrected total	26410.535	100			

Source Primary data; dependent variable: OC; *R* square = 0.168 (adjusted *R* square = 0.021)

6.5 Theoretical Explanation

The notion that demographic diversity affects the individual's work related outcomes has long been substantiated (Riordan and Shore 1997). The individual and relational demographic attributes of employees in organizational context are believed to affect their performance and other outcomes. As van Dijk et al. (2012) in their meta-analysis asserted that the influence of demography diversity depends on the moderator variable, the proposition made in this chapter that OC may play a pivotal role in ensuring that demographic diversity has the positive effect on outcomes of great significance. Since theoretical development to the contemporary applications, OC has been identified as an intervening construct in behavioural researches. OC factors stimulate the human cognitive process which ends with the subjective valuation of these factors. The subjective valuation of organizational attributes is believed to relate with employee well-being and welfare. The whole mechanism through these processes shapes the behavioural outcomes within the organizations. Therefore, by crafting and nurturing certain kind of 'operative conditions' it may be possible to shape the people's actions and behaviours accordingly. A previous empirical inquiry by author (Bamel et al. 2013) of this

chapter also asserted that same. The notion of 'climate for something' also reinforces our presumptions that by creating a climate for diversity, organizations can optimize the 'two edge sword' of diversity. The theoretical framework (Payne and Pugh 1976; Schneider and Reichers 1983) of climate divulges that an 'operative climate' or 'climate for something' can be crafted by the actual identifiable characteristics, properties and conditions of the organization.

Social identity (Turner 1982) and social categorization theory (Tajfel 1981) describe the theoretical perspective of demographic diversity and its potential impact on behavioural outcomes. Per se the Social identity approach indicates that self-concept or individual identity causes behavioural anomalies. Whilst it also substantiates the occurrence of common group occurrence as it purports that the individuals who are having some common attributes develop certain kind of 'in group' and 'out group' favouritism (Tajfel 1981). Thus, the element of social interaction though with limited scope can be sensed in the social identity approach itself. Field theory by Lewin (1951) first time talked about the functions of social environment/climate on the individual behaviour and describes that behaviour of an individual is a product of the individual and the environment which neutralizes the dominance of the individual's traits on their behaviour. This approach argued that a 'socially structured' field exists within the individual and through shared group norms, values and understandings, the large numbers of people can be motivated to act in coherent and meaningful ways rather than idiosyncratic beliefs (Reicher et al. 2010). Another possible argument that OC can be referent to certain 'operative condition' is reflecting from the notion that climate is a multilevel construct and can exist at various levels of abstraction, i.e. climate at group level, climate at department level, climate at business unit level and climate at organizational level (James and Jones 1974). Thus, when organizational members would perceive organizational activities in equivalent manner, this also minimizes the scope of inconsistencies in their expectations and behavioural outcomes (Hayes et al. 2002).

6.6 Implications

6.6.1 Practical

The present study is important for organizations from many perspectives. For one, it holds the potential of generating a feeling of unbiased treatment and thus leading to a higher cohesiveness among employees. Second, it may generate the equal perception of advancement of opportunities in the organization and thus raising the employee's attitudinal consequences as well as their behavioural consequences in the form of higher commitment levels and citizenship behaviours. Once the 'double edge sword' of demographic diversity is channelized into a useful resource

leveraging through OC, it can be put to do wonders in the organization. Instead of fearing that diversity would lead to conflicts, the managers are advised to spread awareness of the benefits of having different opinions for problem-solving and decision-making tasks. Further, in order to get the desired behaviour organizations can establish such organizational processes which are equally perceived by its members. Thus, it may be recommended to maintain perceptual consistency regarding OC. The study also provides insights for the tough job of recruiters. The recruiters do not have any control on the demographics at the time of recruitment without compromising on the competency or talent. By having a confidence that their policies and processes are capable to handle the diversity issue, they may be able to get best people onboard. Equally perceived climate may also result into the avoidance of inter-group conflicts resulting to more collaborative performance. Therefore, the present study may help organizations to review their diversity management policies and consider focussing on providing a better organizational climate.

6.6.2 Theoretical

The present study opens various avenues for future research. First, empirical studies can be undertaken to support the proposition made in this chapter. Second, studies can be taken up to design and validate the metric specific to 'climate for diversity'. Further, a comprehensive study can be taken up to examine the moderating effects of various dimensions of organizational climate on demographic-outcomes relationship.

6.7 Conclusion

We have proposed that an organizational climate may play a moderating role between the relationship of demographic diversity and individual and organizational outcomes. Also, it holds the potential to ensure that the influence is in the positive direction if it is perceived equally by the organizational members. We find few dimensions related to climate for diversity but more research is needed in this direction to bring forth a specific measure for it. Overall, the study shows the potential value of focussing on organizational climate to manage the demographic diversity in a way so as to get desired individual and organizational outcomes.

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Chapter 7
Impact of Workplace Spirituality on Learning Commitment

Chitra Khari and Shuchi Sinha

7.1 Introduction

Changing business environment demands continuous organizational learning (Maurer 2001; Srivastava 2016; Sushil 2013), which enhances an organization's competitive advantage (Adil 2015). Organizational learning is affected by continuous individual learning in the organization (Senge 2003) among other factors. Self-directed individual learning is gaining greater ground in the organizational context as organizations are keen for employees to shoulder more responsibility for their development (Maurer 2001). Perceived skill deficiency, perceived benefits, self-efficacy, organizational commitment, managerial support, work environment, age and education influence individual learning in organizations (McEnrue 1989; Noe and Wilk 1993; Wolters et al. 1996; Maurer et al. 2003; Kyndt and Baert 2013). Previous scholarship has indicated that actual learning participation is predicted by the willingness to learn which is further affected by an employee's positive attitude towards learning (McEnrue 1989; Maurer 2001; Maurer et al. 2003).

Research on workplace spirituality has flourished in the recent past and has evidenced the favourable consequences of embracing spirituality at workplace in terms of employee's positive self-concept, enhanced organizational identification, commitment and, prosocial behaviours (Ashmos and Duchon 2000; Milliman et al. 2003; Pawar 2009; Kazemipour et al. 2012). Inadequate attention however, has been given to investigate its linkage with employee's willingness to learn, which

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constitutes the primary predictor of actual individual learning behaviour (Ajzen 1991; Maurer 2001; Maurer et al. 2003).

Acknowledging the blooming allurement towards workplace spirituality and the importance of individual learning, we argue that when employees experience spirituality at workplace, they develop a positive attitude towards learning which in turn positively affects their learning commitment. This chapter aims to present a conceptual framework through employing the Theory of Reasoned Action (TRA), elucidating how the employee's workplace spirituality experience influences the employee's learning commitment. This chapter provides implications for employee development, organizational development and organizational learning.

This chapter is organized as follows: first, we delineate the prominent scholarship of workplace spirituality and individual learning. Then we present the set of propositions outlining the conceptual linkage between workplace spirituality and individual learning commitment. The last section concludes with discussion and implications.

7.2 Workplace Spirituality

The area of workplace spirituality has gained impetus in the recent past. Spirituality at workplace movement has recently gained strength due to its positive outcome for both, the employees and the organization. Workplace spirituality (WPS) has been found to enhance employee retention, well-being, job satisfaction, organizational commitment, and citizenship behaviours and organizational performance (Ashmos and Duchon 2000; Milliman et al. 2003; Jurkiewicz and Giacalone 2004; Kinjerski and Skrypnek 2006; Moore and Casper 2006; Pawar 2009; Karakas 2010; Gupta et al. 2014; Houghton et al. 2016; Pawar 2016). Although initially considered a difficult construct to operationalize due to the subjective nature of the phenomena, many definitions have emerged (Ashmos and Duchon 2000; Petchsawang and Duchon 2009; Liu and Robertson 2011) indicating that the concept is moving to the next phase of development from being a nascent concept (Kinjerski and Skrypnek 2006; Sheep 2006; Houghton et al. (2016). At the individual level, Houghton et al. (2016) reviewed a decade long scholarship on WPS and concluded that innerlife, meaningful and purposeful work and sense of community have emerged as the common agreed dimensions of WPS. The most notable and widely used definition of the construct is given by Ashmos and Duchon (2000) who first conceptualized workplace spirituality in terms of—innerlife, meaningful work, and sense of community. They defined workplace spirituality as the "recognition that employees have an inner life that nourishes and is nourished by meaningful work that takes place in the context of community" (Ashmos and Duchon 2000, p. 139). Later on Milliman et al. (2003) added the fourth dimension of alignment of values. Jurkiewicz and Giacalone (2004) defined workplace spirituality at the collective

level in terms of the provision of the organizational climate identified with universal values such as integrity, humanism, trust, benevolence, receptivity, generativity, mutuality, responsibility, justice and respect. The cultivation of these spiritual values in an organization promotes individual interest while fostering collective interest; resulting in improved performance, competitiveness and organizational sustainability (Jurkiewicz and Giacalone 2004; Thaker 2009).

7.3 Individual Learning

Organizational learning, which adds to the competitive advantage of an organization, is shown to be affected by individual learning in addition to contextual factors (Antonacopoulou 2006). Increasing competition and organization's concern for cost effectiveness has created greater pressure for self-directed learning in organizations (Ellinger 2004) which requires employees to engage actively in identifying and engaging with any opportunity to learn (Manz and Manz 1991); helping them to maintain their employability and marketability (Ellinger 2004).

Simons (2000) defined learning as "the process through which people construct collective meaning and develop and construct their perspectives of situations" indicating that learning is a mindful and goal-oriented act (Sun 2003). Individuals are likely to engage in learning due to perceived skill deficiency, perceived benefits, lack of self-efficacy, greater organizational commitment, managerial support, work environment, age and education (McEnrue 1989; Noe and Wilk 1993; Wolters et al. 1996; Maurer et al. 2003; Kyndt and Baert 2013).

Ajzen and Fishbein (1975) in the theory of reasoned action (TRA) argue that actual behaviour is determined primarily by behavioural intention. Intention represents the individual's willingness to perform the action. It denotes the extent of hard work and effort that an individual is willing to exert to execute the behaviour. Stronger intention to execute the behavior reinforces the likelihood of its performance (Ajzen 1991). Behavioural intention is affected by the attitude directed towards the behaviour and the subjective norms of the significant referent groups (Ibid.). Attitude towards the behaviour has come forth as the strongest predictor of behavioural intention (Chennamaneni et al. 2012). Attitude represents a judgement regarding the behavioral inclination or disinclination towards an object, situation or person (Altmann 2008). Attitude is shaped by the behavioural beliefs about the behavioural outcomes and the assessment of these outcomes (favourable or non-favourable) (Ajzen 1991). Subjective norms are decided by the normative beliefs about the support or resistance exercised by the significant referent groups to execute the behaviour (Ibid.). In this chapter, we focus on the influence of attitude (learning attitude in present chapter) on behavioural intention (learning commitment in this case).

Previous scholarship has indicated that actual learning participation is predicted by an individual's willingness to learn, which is further decided by the employee's positive attitude towards learning (McEnrue 1989; Maurer 2001; Maurer et al. 2003).

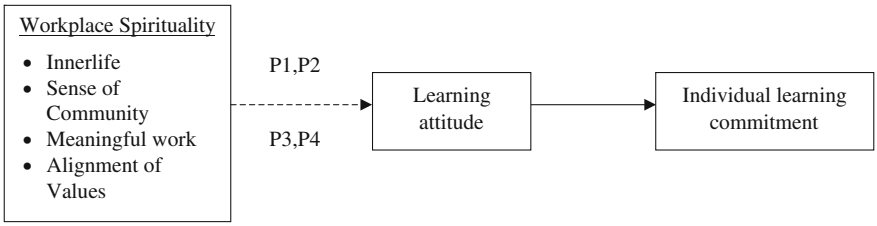

Fig. 7.1 Theoretical framework for elucidating the relationship between workplace spirituality and individual learning commitment (the chapter aims to elucidate the linkages represented by *dotted lines* in the proposed model. The linkages represented by *solid lines* have already been established)

Research has noted the seminal role of cognitive and affective elements in influencing learning attitude (McEnrue 1989; Maurer 2001; Maurer et al. 2003). Tsai et al. (2007, p. 162) defined employees' learning commitment in terms of the "psychological state of employees' willingness to learn new knowledge and skills continuously for their firm's benefits and for themselves". This willingness to engage in learning activities benefits both the learner and the organization (Ellinger 2004) and is decided by the employees beliefs with respect to the favourable outcomes resulting from learning (such as joy in helping others, positive self-concept) (Noe and Wilk 1993). Kyndt and Baert (2013), in a systematic review concluded that, learning willingness is related positively with actual learning participation.

In the succeeding section, we present a conceptual framework and a set of propositions as depicted in Fig. 7.1; elaborating how the spiritual experience at workplace opens employees towards learning by providing the motivation to learn that influences their learning attitude and consequently learning commitment.

7.4 Conceptual Linkage Between Workplace Spirituality and Learning Commitment

7.4.1 Innerlife

The WPS dimension of innerlife relates with the admission of the spiritual self in oneself and others (Ashmos and Duchon 2000). Employees who score high on this dimension encounter positive experiences of fulfilment, joy, enthusiasm and identify collectively with others through viewing one's existential journey with the collective whole (Piedmont 1999). It means such individuals possess higher emotional resources at their disposal, which motivate employees to invest in learning endeavours (Noe et al. 2013). Previous research has indicated that negative emotions erode (Major et al. 2006) and positive emotions reinforce intrinsic motivation

towards learning initiatives (Guedes Gondim and Mutti 2011; Noe et al. 2013). This leads to our first proposition,

P1: The innerlife dimension of workplace spirituality will relate positively with an employee's learning attitude.

7.4.2 Sense of Community

The other significant aspect of workplace spirituality is the sense of connectedness with fellow workers, and viewing organization as a community (Ashmos and Duchon 2000; Milliman et al. 2003). As per the need to belong theory, all individuals possess an inherent tendency to belong with others (Baumeister and Leary 1995). The greater this need, the more is the tendency of the individuals to include others in defining self. Consequently, fulfilment of this relatedness need results in the cognitive inclusion and merging of self with others (Ibid.) leading in self-representation shift from "I" to "We" that is triggered unconsciously and automatically (Brewer and Gardner 1996). This enhances the employees' tendency to cooperate and help (Ibid.). Helping behaviours are linked with openness and desire to develop self and others; thereby, positively affecting an individual's learning attitude. Previous research has shown that employees engage in developmental activities as a reflection of prosocial behaviour (Maurer et al. 2002). Tsai et al. (2007) argue that satisfying social relations at workplace predict employees' learning commitment. We propose that:

P2: The sense of community dimension of workplace spirituality will relate positively with an employee's learning attitude.

7.4.3 Meaningful Work

This dimension indicates doing meaningful work where work is seen to contribute to the larger community (Mirvis 1997; Ashmos and Duchon 2000). Employees working for such organizations view their work and others' work as a contribution towards the well-being of the larger society. The sense of contribution to the well-being of others fulfils the individual's need for meaningfulness and helps employees view themselves as a causal mediator in the larger context of things that fosters a positive self-image and self-efficacy in employees (Mirvis 1997; Ashmos and Duchon 2000). Maurer and Palmer (1999) concluded in their study that individuals' intent toward learning strengthens when they perceive that learning affects the lives of others around them. Employees who experience such meaningfulness at work, we argue, would be more open to learning and growth as they would recognize that developing themselves would lead to greater contributions to work and

the larger context. This in turn enhances the positive self-concept of individuals. When employees perceive that others benefit from their learning, the knowledge of this fact serves as an important motivator for engaging in learning initiatives (Maurer and Palmer 1999; Maurer et al. 2002). Meaningful work generates intangible benefits in terms of positive emotions such as joy in work and sense of positive self-concept and competence (self-worth and self-efficacy). Maurer et al. (2002) argued that employees engage in learning activities to reciprocate the benefits received from the organization. Literature has indicated that greater self-efficacy is associated with higher organizational development activities and enhances the employee's likeliness to volunteer for new learning initiatives (Noe and Wilk 1993; Blau et al. 2008). It is therefore proposed that,

P3: The meaningful work dimension of workplace spirituality will relate positively with an employee's learning attitude.

7.4.4 Alignment of Values

The fourth WPS dimension of values alignment relates with the match between the personal and organizational values (Milliman et al. 2003). Stronger congruence results in greater identification and commitment with the organization which consequently make employees consider organization's success as their own (Kolodinsky et al. 2008). Such individuals are more likely to exert extra efforts to contribute towards the well-being and growth of the organization. McEnrue (1989) concluded that employees who psychologically identify with their employer are more willing to volunteer for self-development activities. Hence, it is proposed that:

P4: The alignment of values dimension of workplace spirituality will relate positively with an employee's learning attitude.

7.5 Conclusion

There is a growing interest in spirituality at workplace (Khari and Sinha 2016), in part due to the many positive outcomes that it is evidenced to bring for the employee as well as the employer (See Houghton et al. 2016). Workplace spirituality provides an individual with the feeling of connection with oneself, others and one's work (Mitroff and Denton 1999).When employees work for the higher purpose or the welfare of others, they start experiencing their work to be meaningful as they begin to fathom their role in the bigger picture of serving the higher purpose. This provides them with a sense of joy and energy while executing their work. Employees with stronger sense of meaning and purpose are more likely to

remain in high spirit, are happier, show enthusiasm while executing their work, show high energy levels, are more resilient, and enjoy their work to the fullest.

Limited attention however, has been given to investigate the influence of workplace spirituality on the learning commitment of employees. The chapter attempted to address this literature gap by arguing that when organizations embrace spirituality in the organizational domain, it results in positive emotions such as joy, fulfilment, sense of positive self-concept, organizational commitment and enhances the employees' tendency towards helping others through learning.

In this section, we discuss how organizational practitioners can benefit from the conceptual framework presented in this chapter. The preceding discussions and propositions clearly suggest a positive influence of workplace spirituality on employees' learning commitment; highlighting the importance of managing the precedents of employees' spiritual experience at workplace. In order to achieve this, organizations can inculcate a sense of higher purpose as a component of organizational goals to enhance work meaningfulness (Ashmos and Duchon 2000; Khari and Sinha 2016). Workplace spirituality calls for a paradigm shift in the organizations to make profit within the wider context, embracing a broader perspective by taking responsibility of the world it functions in, by rising above the financial bottom line and serving back to the society (Zohar and Marshall 2004). This can be done through adopting strategic philanthropic activities as suggested by Porter and Kramer (2002), wherein the philanthropic activities align with the larger organizational goals. Research has shown that employees who participate in organization-led community development initiatives perceive their work as meaningful in comparison to those who do not participate (Grant 2008). Management must communicate these initiatives and their outcomes in terms of the social value creation to the employees on a continuous basis as such communication would help to bolster their positive self-concept and self-efficacy which are reported to enhance individual learning (Noe and Wilk 1993; Blau et al. 2008).

Spirituality based interventions such as meditation can be introduced in the organization to enhance the positive emotions of employees (Fredrickson et al. 2008). As per the broaden-and-build theory, positive emotions broaden an individual's mind-sets, enhance one's attention and blur the distinction between oneself and others (Sekerka et al. 2012). Positive emotions provide employees with the emotional resources to seek new information and engage in learning initiatives (Noe et al. 2013). Research has demonstrated that such spiritual practices relate positively with workplace spirituality scores of employees (Petchsawang and Duchon 2012).

Milliman et al. (1999) studied the case of Southwest Airlines and stated 'company as community' as one of the key attributes in organizations with element of spirituality. People in these organizations take pride in their work, have trust in people they work with, and enjoy the interpersonal relationships at workplace. This calls for raising the organization's consciousness from being a separate atomistic entity to an integrated entity functioning as a part of the wider social and natural system (Gustavsson 2001) by adopting a higher purpose to serve back the society

and the environment. Examples can be cited of organizations such as Southwest Airlines, Tom's of Maine and Bodyshop which have successfully fulfilled their economic interests along with social value creation (Karakas 2010). These organizations have adopted and integrated the spiritual values-based organizational culture that enhances the spiritual experience of employees (Milliman et al. 1999; Jurkiewicz and Giacalone 2004).

As per the resource based view and resource management theory, accumulation, integration and leveraging the human resource of any organization acts as a source to gain competitive advantage for organizations (Barney 1991; Ulrich and Lake 1991; Lado and Wilson 1994; Wright et al. 1994; Sirmon et al. 2007). Since individual learning lies at the base of organizational learning (Senge 1990), it is crucial for organizations to strengthen learning motivation of employees.

Literature has shown that employees' age relates negatively with their willingness to undertake organizational development activities (Cleveland and Shore 1992). The lack of self-efficacy has been reported to be one of the causes for lack of learning motivation (Maurer 2001) among older employees. The extant WPS scholarship has indicated that integration of spiritual aspect in organizational context enhances employee's self-efficacy and instils positive self-concept (Mirvis 1997; Ashmos and Duchon 2000). Integrating WPS can therefore, help to manage learning amongst older employees.

Although this chapter suggests valuable insights for the intrinsic source of motivation for self-directed learning in organizations, the propositions demand further empirical validation to bolster confidence in the relationships proposed. In addition to individual factors, contextual factors have been shown to influence behavioural intention by exerting normative pressures from significant others (Ajzen 1991). Previous research has noted the significance of appreciative and supportive organizational culture in influencing individual learning (Kyndt and Baert 2013). Role of spiritual values-based climate (characterized by humanistic values of benevolence, respect, trust, generativity etc.) in influencing learning in organizations can be explored as future piece of work.

Previous research has drawn attention towards the importance of individual characteristics such as personality on voluntary activity of self-directed learning (Brockett and Hiemstra 1991; Maurer and Tarulli 1994). Major et al. (2006) concluded that proactive personality and Big Five dimension of personality—extraversion, openness and conscientiousness predicts motivation to learn. Personality scholarship has suggested spiritual trait to be the sixth dimension of personality in addition to the Big Five personality dimensions (Piedmont 1999). Piedmont (1999, 2004, 2007) asserted that individuals who score high on spiritual personality trait have the capacity to experience underlying unity and bonding with all through transcending the physical boundaries, which in turn enhance their tendency for more prosocial behaviour. Keeping in view the predictive role of

personality, the impact of spiritual personality trait in addition to Big five personality dimensions on the learning motivation of employees can be pursued as future strand of work.

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Part III
Operations and Technology Management

Chapter 8
Green Supply Chain Management Drivers Analysis Using TISM

Sheetal Soda, Anish Sachdeva and R.K. Garg

8.1 Introduction

Across the world, an increased concern for ecology and environment is being witnessed, calling for conservation of planet's resources and its environment. As a significant outcome of the same, companies are being compelled tacitly to adopt eco-friendly practices all through their supply chain (Chien and Shih 2007). In present times, issues like environmental conservation and climatic changes hold people's attention like never before in past (Intergovernmental Panel on Climate Change 2007). In context of business strategy making and management functioning with regard to ill effects of manufacturing/production undertakings on environment, organizations are assuming significant role as responsible centers in the bigger gamut of social setup to preserve environment and ecology.

Over the last few decades Green Supply Chain Management (GSCM) has emerged as a fascinating concept that is rapidly drawing interest at the end of industries in addressing and augmenting their eco-friendly performance (Srivastava 2007). Rao and Holt (2005) state "GSCM is an important organizational philosophy, which plays a significant role in promoting efficiency and synergy between partners, facilitating environmental performance, minimal waste, cost savings to achieve corporate profits and market share objectives, through environmental risks and impacts reduction, while it improves the ecological efficiency of organizations and their partners." If GSCM is effectually executed by a firm, it helps the later in

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preserving and expanding its competitive gains amongst other contestants in the market (Zhu and Sarkis 2004).

With insatiable appetite for power, developed and developing economies all across the world are gearing up to augment their power generation capacities—most of which are going to pose a serious threat to global environment. Power Industry has been identified as the second largest polluting industry, owing to Green House Gasses (GHG) emissions caused by burning of fossil fuels. GSCM finds its extensive application in Power Industry, and has the potential to deliver cleaner energy, coupled with economic gains for the practicing organizations. The power companies are waking up to the fact that green operations are not only eco-friendly, but make acute business sense also. Certain Indian power companies have reworked on their supply chains, but still much has to be done by many others. The opportunities thrown forward by intensive GSCM practices for State-Owned Power Companies (SOPCs) call for a comprehensive study about the possibilities that can be explored for making existing supply chains greener.

Investigation of mutual relationship among drivers of GSCM in context of Power Industry is essential to understand their relative importance in making the industry greener. Finding out leading drivers from the whole lot of suggested drivers and examining their inter-relationships, in context of Power Industry of Punjab, a state in North India by applying TISM technique through expert's judgments, was a handy way to establish the relative effectiveness of the drivers in making the industry more eco-friendly.

This chapter has a sequential structure comprising a literature review with relevance to the concept of GSCM and Power Industry of Punjab, wherein it is attempted to identify prominent drivers of GSCM in Power Industry. The subsequent section of the chapter deals with problem description. There are a number of major drivers of GSCM in context of Power Industry of Punjab, the relative effectiveness of whom, in motivating the adoption of GSCM measures and their inter-relationships, is to be known. The subject forms the axial problem, for which solution methodology is presented with the help of TISM methodology. The subsequent section sums up the findings, wherein deductions are made from sequential steps of calculations involved in TISM technique. The structures of influencing drivers are deliberated in the section titled "Results and Discussion". Finally, the closing section presents the conclusions of the analysis undertaken.

8.2 Literature Review

8.2.1 Indian Power Industry and Green Supply Chain Management

With an installed capacity of 263.389 GW by the mid of 2016, India is fifth largest global producer of power. On the front of energy generation, India has made a

quantum leap of adding more than 180 GW in a period of less than 25 years. In 1991, the country had a capacity of just 66 GW which has risen to 263.389 GW in 2016.[1] As per the estimates of International Energy Agency, the country is poised to augment its generation capacity anywhere between 600 and 1200 GW by the mid of this century. This will translate into huge detrimental impact on environment, until and unless we switch over to more eco-friendly ways of power generation, transmission, distribution, and consumption. In short, the need of environment-friendly supply chain is of paramount importance, which is alternatively and popularly called as "GSCM".

GSCM is a novel concept globally, more so in Indian context. The adoption of GSCM practices by Indian firms on percentage basis is abysmally low. Since it is a general perception that GSCM initiatives are cost intensives, there is a general tendency that the same are not embraced as seriously by Indian firms, as compared with their western counterparts. Limited adoption of GSCM measures can also be attributed to not-so-stringent enforcement of law of land pertaining to environmental conservation and curbing of pollution owing to industrial/occupational activities. The concept, if has generated any interest in itself, is limited only to academic circles; and there are very few industrial/corporate players who have earnestly and genuinely made conscious steps to incorporate GSCM as an integral part of their day-to-day working. GSCM has transpired into a wonderful management technique for companies to secure gains, efficiency, and market share goals by cutting down ecological risks and their subsequent consequences (Van Hoek 1999).

In context of Indian power sector, the lion's share of which, till recently, lied with State Electricity Boards (SEBs); little efforts have been made by majority of power companies to go for eco-friendly measures, to the maximum of their potential. Though the PSUs owned by Central government as well as new generation private players have exhibited interest in GSCM practices, the role of erstwhile SEBs and other state-owned, state-level power utilities has not been much encouraging. But constrained by regulations and competitive market structure, the SOPCs are gearing up for a major drive to practically imbibe GSCM—because it not only leads to securing environmental concerns, but also secure substantial savings in financial terms. The spurt in pro-environment movements and legal stipulations and regulations, as witnessed in the last 10 years, has precipitated into unanimity that industrial progress should be coupled with environmental conservation, which in process will give a natural push to adoption of GSCM (Sheu et al. 2005).

8.2.2 Drivers for Application of GSCM in Power Industry

As the concept of environmental management gained attention among diverse operational and academic realms, the notion of green supply chain (GSC) started

[1]India Power Market Outlook to 2025, Update 2015 – Market Trends, Regulations, and Competitive Landscape

emerging in the works of various authors, during past few decades. The literature on GSC got a spurt in the beginning of 1990s, with the conception of themes such as Environmentally Conscious Manufacturing Strategy, Supply Chain Management, Corporate Environmental Management, etc. (Zhu and Sarkis 2006). A study by Holt and Ghobadian (2009) tried to ascertain the extent and prominent attributes of implementation of GSCM in context of United Kingdom's manufacturing sector. Furthermore, the work investigated the motivating forces behind environmental behavior on the part of companies, the particular management practices emanating from them; along with the inter-relationships they share. Significant factors for the implementation of GSCM practices were explored by Hu and Hsu (2010) in perspective of electrical and electronics industries of Taiwan with relation to directives of European Union. Resultantly, 20 crucial factors were determined under four broad categories viz. Suppliers and Sourcing, Recycling of the Product, Organizational Inputs and Product Life Cycle Management. In his study, Trowbridge (2001) differentiated between internal and external drivers for executing GSCM with relation to a Chip-manufacturing firm. Among the Internal drivers were willingness to improvise upon risk management arising from probable interruptions in the supply chain, and working closely with suppliers/vendors to look out for substitutes in terms of machines and material that is more environment-friendly in nature. Seven sets of green supply chain initiatives were identified by Holt et al. (2001) for improving upon the environmental performance of an organization, i.e., Governments, Trade Chambers and Sectoral Associations, Partnership-based firms, Discrete Companies, Business-facilitating bodies, Non-Profit Green Business-Support Organizations, and Eco-friendly Corporate Clubs.

The relationship between Supply Management Capabilities and Green Supply Practices was studied by Bowen et al. (2001) to identify intrinsic drivers for implementation of green supply mechanism featuring factors like Strategic Procurement and Supplies, Corporate Pro-Environmental activity and Supply Management Competencies. Walker et al. (2008) did a literature review on GSCM and discovered the factors that promote or retard implementation of GSCM initiatives at the end of an organization. The internal drivers identified from the study included organizational factors and external drivers included subjects like suppliers, competitors, customers, regulations, society, etc. They carried out interviews at seven different public sector and private sector enterprises and identified more internal barriers like cost and want of legality, coupled with external barriers like limited dedication toward the green cause on the part of the suppliers and industry-specific barriers. Rao and Holt (2005) have stated that an organization can go for greening individual segments of a supply chain, which would result in Integrated GSC. This will further lead to increased competitiveness and higher economical and operational performances. In his study, Lee (2008) determined that buyers influence, institutional interventions, and readiness to execute GSC act as major drivers for firms to adopt GSCM practices. In a separate study, it was observed that key factors leading to healthy implementation of GSCM agenda include resolve on the part of top brass of a company; comprehensive contribution by the employees; training and awareness programs on eco-friendly issues; Green Product/Process Design; managing the supplier base apropos green

agenda, and measurement/information management about the data precipitating related with GSCM implementation (Wee and Quazi 2005).

There is plethora of literature on the drivers of GSCM for various industries, particularly those associated in manufacturing sector. On the contrary, Power Industry—considered in its integral form, i.e., generation, transmission and distribution—has remained relatively unattended, in context of studies undertaken with reference to implementation of GSCM. Power Industry being a pollution-intensive industry, this is strange that there is limited research work on making its supply chain green and eco-friendly. Though enough technological advances have been made on the generation part of the industry, where undoubtedly new inventions have led to considerable arrest of pollution while generation of energy, the industry has never been addressed holistically with regard to implementation of GSCM in all its core sections. Much study and research has been carried out on clean energy and renewable energy, but the same can be treated as specialized subjects of study and do not form, in themselves, the complete Power Industry.

As governments are pushing for stern compliance of environment-related laws and regulations, with relation to emission standards, the time has come for Indian power companies to go full throttle with implementing GSCM in practice. Thus, it is very important to identify major drivers affecting implementation of GSCM and establishing a mutual relationship among these drivers. Ten major drivers associated with implementation of GSCM in Power Industry in the state of Punjab are considered. The chosen drivers are mentioned in Table 8.1, as per the literature and discussions with industrial experts.

8.3 Problem Description

Punjab has been one of the more economically developed states of the country, with high rate of per capita energy consumption. The state's power sector has been instrumental in its growth, as much of the agriculture sector and MSMEs thrive on the power made available by the SOPCs. Any improvement in their supply chain is sure to translate into perceptible growth in the economy of the state. PSPCL (Punjab State Power Corporation Limited), the power generating and distribution company, and PSTCL (Punjab State Transmission Corporation Limited), the power transmission company, are SOPCs based in the state of Punjab, and are representative of most of the modern-day power utilities operating in India, who have been transformed into corporations from the erstwhile avatar of SEBs. The erstwhile SEB, i.e., Punjab State Electricity board, was bifurcated into PSPCL and PSTCL in 2010, in accordance with the recommendations of CERC (Central Electricity Regulatory Committee), and thereby presents an appropriate option to study a modern-day state power utility. The relatively new set of power utilities make them more conducive for study purpose, as it is easier to identify and propose changes in a new setup, rather than those which are old and are characterized by rigid and stiff pattern of operations. The findings with regard to these SOPCs will be more or less

Table 8.1 Drivers of GSCM in the case of power industry

S. No.	Driver	Explanation	References
1	Regulatory requirements	Governments at various levels, frame various laws/ordinances/regulations pertaining to environment conservation, which binds various industries to mandatory incorporate eco-friendly measures in their operations, or offer services conforming to particular environmental standard(s). Defying such laws and regulations invite punitive action on the part of the erring corporate house	Ray and Richardson (2009), Lilly (2008), Walton et al. (1998), Walker et al. (2008), Zhu and Sarkis (2006)
2	Economic benefits	GSCM measures tend to reduce wastages and make optimum use of the available resources. Certain GSCM measures also tend to streamline the supply chain by doing away with its obsolete sections. Such measures translate into economic benefits by eliminating the avoidable cost associated with the supply chain	Stevels (2002), Rao and Holt (2005), Zhu and Sarkis (2004), Purba (2002), Rao (2002), Urban and Richard (2009)
3	Brand image	With growing consciousness regarding environmental concerns on the part of customers, the companies tend to gain advantage in terms of market share and brand image by adoption of eco-friendly measures in their corresponding supply chains	Katz (2007), MacKillop (2009), Chen (2008)
4	Quality upgradation	Invariably, GSCM measures tend to augment the quality of the final product, by adoption of latest green technology. The quality of manufacturing processes and supply chain components also receive a fillip on the count of quality attributes	Rao and Holt (2005), Zhu and Sarkis (2006), Zhu et al. (2005, 2007a, b, 2008a)

(continued)

Table 8.1 (continued)

S. No.	Driver	Explanation	References
5	Top management commitment	The vision adopted by the top brass of an organization tends to travel downward and reflect in the entire organizational work culture. Green policies and procedures directed by the top management, as part of their commitment to environment, act as a big driver of GSCM implementation	Digalwar and Metri (2004), Hamel and Prahalad (1989), Mudgal et al. (2010), Singh and Kant (2008), Zhu and Sarkis (2007), Ramakrishna (2006), Allen et al. (2002)
6	Eco design	Designing of machinery, products, and manufacturing infrastructure helps in being eco-friendly. Designing of fuel-efficient/energy-efficient products and designs that work on natural/renewable/environment friendly resources help a lot towards GSCM implementation by an industrial establishment	Gutowski (2001), BearingPoint (2008)
7	IT implementation	IT implementation is a big leap towards automation and self-service. IT-enabled tools have helped immensely in systemizing the supply chains by making them faster, accurate, convenient and orderly. Across various supply chains, the adoption of IT tools has translated into gains on environmental front—in terms of better designing, better supply chain monitoring, saving of resources, etc.	Yu and Hui (2008), Rogers and Ronald (1998), Sarkis et al. (2007), Yu (2007), Mclaren et al. (2004), Ravi and Shankar (2005), Alemayehu (2008)
8	Green options	In general, to every resource/technology, there exists its green alternative, too. Substituting existing resources and technologies in favor of greener options helps a lot in greening the Supply Chain	Our contribution driver

(continued)

Table 8.1 (continued)

S. No.	Driver	Explanation	References
9	Customer's involvement	Customer, though generally not considered as a part of supply chain, is an integral component of the same. His role in efficient usage of products, reduction of wastage and disposal of waste is crucial to greening of supply chain	Alhola (2008), Zhu et al. (2008a, b), Reijonen (2011), Rao and Holt (2005)
10	Environmental/social responsibility	The sense of being responsible towards the society, with due consideration to being eco-friendly, on the part of people associated with a particular supply chain is a big driver of GSCM implementation in any organization. Voluntary and intrinsic concern for preserving environment helps a lot in greening of a supply chain	Mudgal et al. (2010), Perron (2005), Seuring (2004), Sharma (2000), Henriques and Sadorsky (1999)

applicable on state-owned power companies based on other parts of the country, as well. In nutshell, SOPCs of Punjab are near-ideal choices to have a fair assessment of GSCM implementation in their operational domains, since the two SOPCs are identified with the typical power utility set up in most of the states of the country, and are perched on a threshold to reform their supply chains, with an intent to leave the remnants of operational mediocrity behind.

Identification of relationships between the various drivers crucial to the adoption and implementation of GSCM in power industry of India is of paramount importance. Extensive study of the academic and research-based literature helped in the identification of major drivers (9 in number). One driver was identified while analyzing the opinions extended by experts on the subject under consideration, viz., Green Options—which relates with environment friendly technologies as well as renewable, nonpolluting sources of energy. Amalgamation of eco-conserving technologies as well as tapping of nonconventional sources with little or no detrimental effect on environment is a domain which has the potential to affect the popularization and effectiveness in a substantially affirmative manner, by making the supply chain of the industry greener than before. As per a study carried out by McKinsey & Company Inc., 2009, there are more than 200 practices and known technologies in place, at the heart of emissions reduction and augmenting energy efficiencies. The objective is to identify the major factors that propel the green culture in Indian power setup, and the interplay of these factors among themselves on one-to-one basis. The conclusive findings will be crucial in identification of the

relative significance of the driving factors, and gauging the priority areas which can be worked upon to augment the GSCM culture in power companies of India. The country is pushing ahead on the path of power reforms and modernization of the entire power scenario. The desired results of these initiates will remain incomplete, in the absence of deployment of GSCM measures extensively across power companies of the country. The findings can prove useful in extending leads in this direction and helping achieve the green goals of power companies in a more systematic, target-based, and priority-based manner. The significant drivers at the heart of GSCM adoption and implementation in the case of Power Industry of Punjab, which has been taken as a target area, are enumerated in Table 8.1.

8.4 Solution Methodology

ISM (Interpretive Structural Modeling) is a method for analyzing complex problems and acts as a brilliant analysis tool. First proposed by Warfield in 1973, ISM is a potent tool for analyzing complex systems with interplay of many factors and variables. Sage (1977) has stated that ISM is deployed as a tool for instilling regularity and sense of orderliness in the complicated inter-relationships that various elements of a system share with each other. ISM technique calls for gathering expert opinions by implementing a multitude of methodologies, viz., Nominal Group Technique, Brainstorming, and Affinity Diagramming, for precipitating appropriate inter-relationships amongst them (Ravi and Shankar 2005). While deploying ISM, the digraph can possibly be construed at two different levels, i.e., (1) Nodes, (2) Links, wherein the nodes signify the respective factors and links signify the contextual inter-relationships that they share with each other and the direction of the nature of relation attributed with an element-pair, individually. This is to be noted that interpretation of the links is weak in such cases, as it is marked with a lack of information as to how the mechanism underlying the link operates. The methodology does extend information about the contextual relationship; and also provides to the direction of alignment between the two; yet it fails to put forth the mechanism that determines the direction of movement of the relationship. TISM is a potent tool to address this weakness of ISM by deploying Interpretive Matrix (Sushil 2005a) and that further helps in the development of framework and methodology of TISM for theorizing vaguely expressed models and theories. The explanation of the mutual relations can be depicted by the side of the link connecting the pair of factors having the relation. By deducing both the nodes and links inherent to the structural model, an ISM can be elevated to the standard of a TISM, which possibly has better applicability in real-life situations and thus is of greater use to researchers and practitioners (Saxena et al. 2006; Nasim 2011; Wasuja et al. 2012) in many context and case situations. TISM was used for modeling the drivers affecting the implementation of GSCM in the Power Industry. The TISM (Sushil 2012, 2016) is a pioneering advancement of ISM (Warfield 1974), that is used to create a graded structure of the set of chosen variables. The TISM relates with

elucidation of inherent elements by a methodical, iterative usage of Graph Theory. Consequently, a directed graph is structured featuring the set of variables associated with a complex system. The graph is an effective way to study a vague, poorly expressed model by transforming it into an understandable, comprehensible, and well-systematic model that can be used for precipitating a multitude of interpretations. This is a new Qualitative-Modeling practice that is deployed by researchers in diverse fields of study (Wasuja et al. 2012; Prasad and Suri 2011; Nasim 2011; Srivastava and Sushil 2013).

The basic procedure of execution of TISM is given below:

Step 1: *Categorization and Explanation of Elements*
Various drivers affecting the implementation of GSCM for the Power Industry are identified from extensive literature review and opinions invited from power industry experts (Table 8.1).

Step 2: *Defining the Contextual Relationship Between the Elements*
The structural model of the constituent elements of a system can be built only if the inter-relationships between the said elements are clearly laid down. In this step, the focus is on dependence of Driver B on Driver A, i.e., Driver A will enhance or influence in an affirmative way, the occurrence of Driver B.

Step 3: *Interpretation of Relationship*
Interpretation of Relationship is the foremost step in improvising upon the conventional Interpretive Structure Modelling. In ISM, the relative relationship points to the attributes of relationship, in accordance with type of structure, nevertheless it does not give any information about the mechanism of the working of that relationship. With the intent of taking the ISM to the higher level, i.e., TISM, it is necessary that the interpretation of the relationship may be clearly laid down as in Table 8.2 for various types of structures. With relation to the present analysis, the interpretation will be "In what way Driver A will influence/enhance Driver B?"

Step 4: *Interpreting the Reasoning of Pair-Wise Comparison*
In order to formulate an SSIM (Structured Self-Interaction Matrix), the initial step is to compare the elements individually with each other. But the subsequent analysis of the comparison is limited only to establishing the course of the relationship. This notion is used in TISM, by responding the interpretive query in Step 3 for each paired comparison. In this technique, the first element is subjected to comparison to all the remaining ones of the system. Corresponding to the inter-relationship between the elements, the responses are to be recorded either in "Y" (Yes) or "N" (No), outlining the underlying reason for the "Y"—(Yes) entries. All the raw elements are compared, and the interpretive relationship emerged mutually between the elements.

Table 8.2 Elements, contextual relationship, and interpretation for the drivers of GSCM in power industry

Code of element	Name of the element	Contextual relation	Interpretation
D1	Regulatory requirements	Driver A will influence/enhance driver B	How or in what way GSCM driver A will influence/enhance GSCM driver B
D2	Economic benefits		
D3	Brand image		
D4	Quality up gradation		
D5	Top management commitment		
D6	Eco design		
D7	IT implementation		
D8	Green options		
D9	Customer's involvement		
D10	Environmental/social responsibility		

Step 5: *Reachability Matrix and Transitivity Check*
A reachability matrix is evolved from the comparison pairs featuring in the Interpretive Logic–Knowledge Base. In the i–j cell, entry 1 is made, if the corresponding entry in knowledge base in "Y". Otherwise, entry is made as 0, for a corresponding entry "N" featuring in the Interpretive Logic–Knowledge Base. This matrix is subjected to transitivity rule to see if the latter is fully established. The transitivity rule states that if X is related to Y and Y is related to Z, then this suggests that X is necessarily related to Z. The concluding updated Reachability Matrix, after conducting the post-transitivity check, is presented in Tables 8.3 and 8.4.

Step 6: *Level Partition on Reachability Matrix*
In accordance with ISM, level partition is undertaken to assess the location of elements with respect to their level (Saxena et al. 2006; Warfield 1974). Thereafter, reachability is established for all elements of the system, along with their antecedent sets. The pyramid's uppermost level will be occupied by elements, which are not able to reach any element above their own level. Consequently, the reachability set for an uppermost-level element will encompass of that particular element; and those alike to which the earlier stated can reach; for instance, those matching to the connected subset. The Antecedent Set for a top-level element will contain the element itself, along with elements reaching from lesser levels, and any element of a strongly connected subset at the upper level. Therefore, intersection of the antecedent and the reachability

Table 8.3 Level partition of drivers—final iteration

Drivers	Level
Regulatory requirements (**D1**)	**IV**
Economic benefits **(D2)**	**II**
Brand image **(D3)**	**II**
Quality upgradation **(D4)**	**I**
Top management commitment **(D5)**	**V**
Eco design **(D6)**	**I**
IT implementation **(D7)**	**IV**
Green options **(D8)**	**IV**
Customer's involvement **(D9)**	**III**
Environmental/social responsibility **(D10)**	**III**

set will be same as the reachability set if the element is at the top level. The upper level elements fulfilling the above-stated requirement should be subtracted from the element set and the exercise is to be made repetitive iteratively, till all the levels are established.

Step 7: *Developing Digraph*
The elements are segregated into levels and are positioned in the shape of a graph. Links are established in accordance with the relationships and are directed and depicted in Reachability Matrix. The relatively unimportant transitive relationships between the elements are eradicated, by undertaking step-by-step examination of the interpretations made earlier. Thus a simplified form of the initial digraph is reached at, which features only those transitive relationships, which are significant in nature (Fig. 8.1).

Step 8: *Interaction Matrix*
The information featuring in the Final digraph will be used to form Binary Interaction Matrix. The various interactions coming in play are demonstrated by entry "1". They are inferred by consideration of requisite explanation from the knowledge base of Interpretive Matrix (Table 8.4).

Step 9: *Total Interpretive Structural Model*
TISM is made by deploying the connective and interpretive information contained within the Interpretive Direct Interaction Matrix as well as the Digraph. The requisite value of elements is, thereafter, mentioned in boxes, replacing the nodes of the digraph. The interpretive explanation associated with the cells of Interpretive Direct Interaction Matrix is represented by means of corresponding links in the structural model. Accordingly, exhaustive interpretation of the structural model, with respect to interpretation of its nodes and the links, is attained. The consequential TISM model of the identified elements is demonstrated in Fig. 8.2.

As per the above, TISM methodology was applied to Power Industry of Punjab.

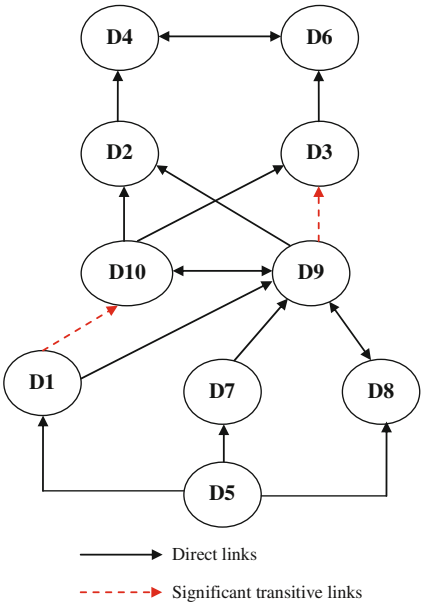

Fig. 8.1 Digraph with significant transitive links

8.5 Development of TISM Model

On the basis of exhaustive review of literature on the subject, and after conducting interviews with the experts/professionals from Power Industry of Punjab, a set of ten drivers was proposed. The prominent drivers recognized as a result of the exercise are mentioned in Table 8.1. To develop the structural outline of the model, it is imperative that contextual relationships between various factors/elements affecting a specific phenomenon must be established, in advance. The contextual linkage between the given drivers of a phenomenon (implementation of GSCM) is summed up in this statement—"Factor A will influence or enhance Factor B". Table 8.2 depicts various elements, their contextual relationship, and interpretations for the drivers at work of GSCM implementation of Power Industry of Punjab. On the basis of the same the interpretive logic knowledge base of the subject issue was created.

The fact that the study entails 10 drivers the total numbers of rows in the developed knowledge base stand at $10 \times 9 = 90$. In order to fill the knowledge base, the authors reached out to experts of the industry and invited their opinions on various issues concerning the subject, as per the nature of the study. The responses elicited from the industry experts were deployed in creating the Reachability Matrix. While chalking out pair-wise comparison, if the affirmation in positive is to the tune of 60%, the same is taken as Y, else N. The affirmations in positive (Y) were subject to analysis in the wake of interpretations extended by the experts; and a collective statement interrogating all the opinions and responses was structured.

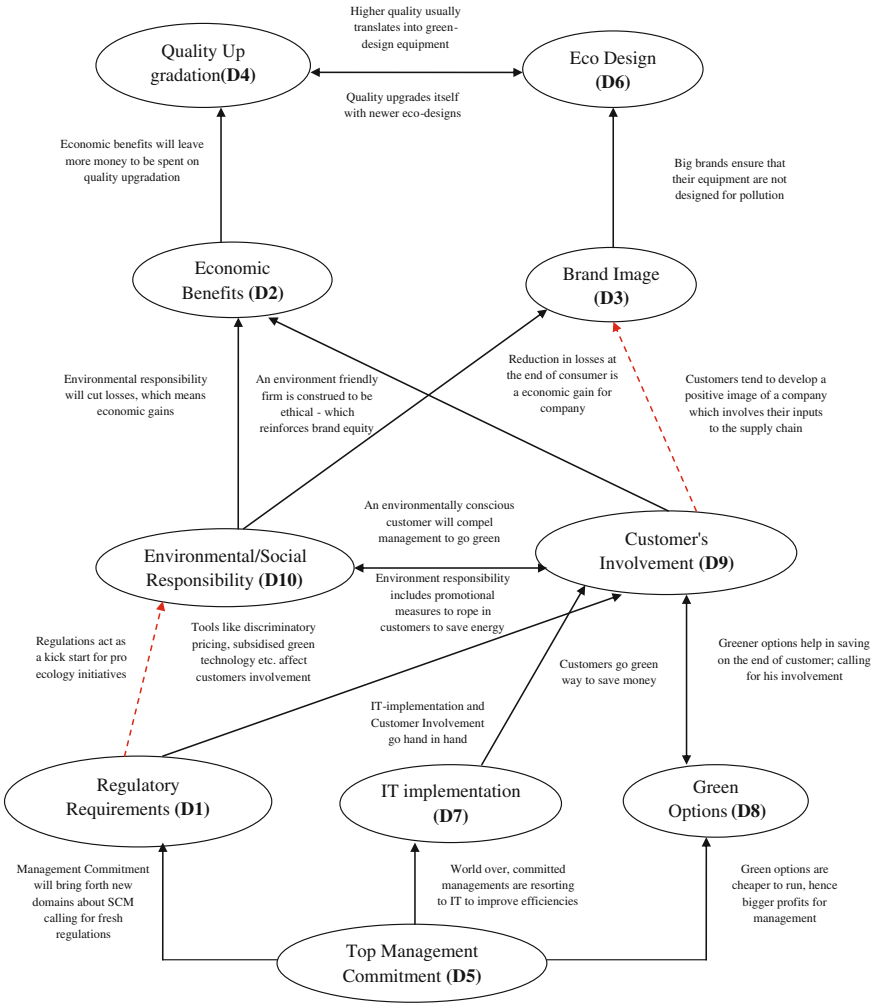

Fig. 8.2 TISM model

Thereafter, the Final Reachability Matrix is developed, which calls for the introduction of the concept of transitivity, so that a number of cells of preliminary Reachability Matrix are populated by inference. The concept of Transitivity can be illustrated with this illustration: Let us say, if A is related to B and B is related to C then this means that A is necessarily related to C. Transitivity forms the most fundamental hypothesis in ISM, and is deployed in Modeling Approach, without fail (Farris and Sage 1975; Sushil 2005a, b). It also serves the advantage of securing conceptual consistency.

The Reachability Matrix was segmented into various levels. From the Final Reachability Matrix, the "Reachability" and "Antecedent" set for each driver were

found (Warfield 1974). The reachability set for an individual driver comprises itself and other drivers, which it may help to achieve. The antecedent set consists of the drivers themselves and other drivers which may help in achieving it. The intersection of both these sets was also derived for all drivers. If the reachability set and the intersection set for a given driver are the same, then that driver is considered to be in level I and is given the top position in the hierarchy (Kannan and Haq 2007). With this partition, iteration 1 is completed. After the first iteration, the drivers forming level I are discarded and the abovementioned procedure is continued in iteration 2 with remaining drivers. These iterations are continued until the level of each driver has been found (Diabat and Govindan 2011). These levels are exploited for the formation of digraph. Digraph is an abbreviation for directed graph, which depicts the mutual inter-relationship between two elements of enablers, corresponding to the numbers consigned to them. Inter-relationship between elements j and i can be depicted by an arrow, pointing from i to j. The relevant digraph with significant transitive links is depicted in Fig. 8.1. The final digraph is given the shape of a Binary Interaction Matrix. The data acquired from Interaction Matrix as well as the digraph is deployed to structure TISM (Fig. 8.2). The graded structure depicted in Fig. 8.2 illustrates the driving force at work while implementing GSCM in power industry of Punjab.

Table 8.3 shows all the levels after final iteration. Table 8.3 implies that the "Quality Up gradation" and "Eco-Design" drivers are positioned at level I and form the top level in ISM hierarchy. The "Economic Benefits" and "Brand Image" drivers are positioned at level II; the "Customer's Involvement" and "Environmental/Social Responsibility" drivers are placed at level III; "Regulatory Requirements", "IT Implementation" and "Green Options" drivers are placed at level IV; and the remaining driver "Top Management Commitment" fall in at level V. The final level of each driver is given in Table 8.3.

8.6 Result and Discussion

Management of Power companies feels considerable challenges in the context of drivers of GSCM implementation. The decision-makers of the organization need to have a sound knowledge of relative importance of the drivers of the subject and the corresponding techniques required to implement them. Considering the selected ten drivers, TISM model was constructed. The interaction between the listed drivers was studied for Power Industry using TISM model.

Building upon the opinions of experts of power companies of Punjab, from Fig. 8.1, it is evident that Top Management Commitment is a significant driver to achieve the regulatory requirements; IT Implementation and Green Options drivers, which in turn, are critical to achieving the Environmental/Social Responsibility and Customer's Involvement. GSCM drivers Economic Benefits and Brand Image are placed at an intermediate level of the TISM model. Quality Upgradation and Eco Design drivers are at the top level of the TISM hierarchy.

8.7 Conclusion

Amalgamation of eco-friendly measures in a conventional supply chain forms an effective tool for improving the environmental performance of companies/industries. GSCM has proved its potential in transforming the processes deployed by firms and products offered by them, on the count of environmental sustainability. Ten drivers, in context of greening the supply chain of power companies of Punjab, were identified by means of study of literature on the relevant topic, as well as through the opinions of industry experts. Thereafter, TISM methodology was applied to find contextual relationships among the chosen drivers. The entire exercise helped to create a model with the help of TISM methodology. Application of TISM is to better understand the factors contributing to implementation of GSCM in power industry provide an intellectual way to analyze the situation and plan the corrective actions to improve upon overall performance of the industry. In general, this methodology of modeling technique finds utility with the researchers, and the resultant model provides deeper insights into the system to the domain practitioners.

It is established that Top Management Commitment is the most potent driver in implementing GSCM in the industry. Conversely, Environmental/Social Responsibility is the least motivating factor when talking in respect of the SOPCs of Punjab. It points toward the fact that in context of the studied state/companies/industry, the green measures manifest when they are "enforced" from top to bottom in the managerial hierarchy, and there is limited consciousness on the part of stake holders in the supply chain to go green. Drivers "Quality Upgradation", "Economic Benefits", "Brand Image", "Regulatory Requirements", "Eco Design", "IT Implementation", "Green Options", and "Customer's Involvement" have similar impact in effecting the implementation of GSCM in the SOPCs of Punjab, and bear significant dependence upon each other. Thus any of them, if assumes prominence, will cast a favorable effect on others in the group which will have a snow balling effect toward the end of GSCM implementation in the studied companies. Conversely, retardation in any of them will have similar effect on other drivers in the group and effect the GSCM implement in a negative way. There is susceptibility to a weakness emanating from the fact that the number of variable associated with the subject has been limited to just ten. A larger number of variables would have certainly augmented the depth of the inferences deduced apropos GSCM implementation in a more comprehensive manner. Nevertheless, the variables chosen are of prominent nature and play significant role in application of GSCM in power industry.

Appendix

See Table 8.4.

Table 8.4 Interaction matrix

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
(a) *Binary matrix*										
D1		0	0	0	0	0	**1**	0	**1**	*1*
D2	0	–	0	**1**	0	0	0	0	0	0
D3	0	*1*	–	0	0	**1**	0	0	0	0
D4	0	0	0	–	0	**1**	0	0	0	0
D5	*1*	0	0	0	–	0	**1**	**1**	0	0
D6	0	0	**1**	**1**	0	–	0	0	0	0
D7	0	0	0	0	0	0	–	0	**1**	0
D8	0	0	0	0	0	0	*1*	–	**1**	0
D9	0	**1**	*1*	0	0	0	0	**1**	–	**1**
D10	0	**1**	**1**	0	0	0	0	0	**1**	–
(b) *Interpretive matrix*										
D1	-	–	–	–	–	–	IT implementation is integral to power reforms (regulations)	–	Tools like discriminatory pricing, subsidized green technology, etc. affect customers involvement	Regulations act as a kick start for pro-ecology initiatives
D2	–	–	–	Economic benefits will leave more money to be spent on quality upgradation	–	–	–	–	–	–

(continued)

Table 8.4 (continued)

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
D3	–	Strong brand image pulls customers which naturally means bigger profits	–	–	–	Big brands ensure that their equipments are not designed for pollution	–	–	–	–
D4	–	–	–	–	–	Higher quality usually translates into green-design equipment	–	–	–	–
D5	Management commitment will bring forth new domains about SCM calling for fresh regulations	–	–	–	–	–	World over, committed managements are resorting to IT to improve efficiencies	Green options are cheaper to run, hence bigger profits for management	–	–
D6	–	–	Green designs make strong brand statements	Eco design is a subset of quality upgradation. Quality upgrades itself with newer eco-designs	–	–	–	–	–	–

(continued)

Table 8.4 (continued)

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
D7	–	–	–	–	–	–	–	–	IT implementation and customer involvement go hand in hand	–
D8	–	–	–	–	–	–	–	–	Greener options help in saving on the end of customer; calling for his involvement	–
D9	–	Reduction in losses at the end of consumer is a economic gain for company	Customers tend to develop a positive image of a company which involves their inputs to the supply chain	–	–	–	–	Customers go green way to save money	–	An environmentally conscious customer will compel management to go green
D10	–	–	Environmental responsibility will cut losses, which means economic gains	An environment friendly firm is construed to be ethical, which reinforces brand equity	–	–	–	–	Environment responsibility includes promotional measures to rope in customers to save energy	–

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Chapter 9
Computer-Aided Process Planning Using Multi-criteria Decision-Making Technique

Prathmesh Todakar, Uday Kumar and Sunil Agrawal

9.1 Introduction

Automation has now become breath of manufacturing. Increasing market demand, quality control and growing product variety are major hurdles managers are facing. Till now we have successfully automated design and machining part through CAD and CAM. To complete the computer-integrated manufacturing (CIM) cycle, we are lagging in planning part. Computer-Aided Process Planning (CAPP) can play a key role, particularly in CAD/CAM integration and therefore, it has been the focus of attention and research. Main focus of the research is to generate easy and widely implementable CAPP method.

CAPP has been adapting to multiple approaches such as variant, generative and semi-generative approach. Also artificial intelligence (AI) has opened the wide spectrum of research in the field. A large number of companies have acquired CAPP systems for integration of design and production and to compensate the shortage of skilled process planners (Marri et al. 1998). In spite of the fact that many CAPP systems have been developed, their effectiveness is still far from satisfactory, and many large companies had to establish their own research groups to develop their own CAPP systems. It is not possible for each and every manufacturer to invest a big sum of money on planning modules. Hence, an easy and low-cost CAPP method is needed in this scenario.

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9.2 Literature Survey

Knowledge Base System (KBS) is the main component of a CAPP system. It can be assumed as the brain of the whole body, working in accordance with other parts to give output plans. KBS has seen various techniques for its development.

Yeo et al. (1991) used knowledge of an experienced process planner and NC programmer by employing an expert system. Giusti et al. (1989) developed KAPLAN—a KBS using IF-THEN rules for rotational parts. Wong and Siu (1995) have proposed an expert system for process selection and sequencing for prismatic parts. Van't Erve and Kals (1986) developed XPLANE—a generative CAPP system that uses an expert system for automatic tool selection, machining operation selection and sequencing. Yeo (1994) adopted a software tool, 'GoldWorks III' to develop a knowledge-based feature modeller for machining. A KBS for hole-machining process selection has been reported by Khoshnevis and Tan (1995). An expert system has been developed by Lin and Yang (1995) for fixture planning in face milling. Zhao et al. (2002) developed a KBS for cutting tool and condition selection for turned components starting from a CAD model.

From the above literature survey, it appears that knowledge-based approaches hold a lot of potential for application in automation of process planning. Present chapter is based on preparing an efficient knowledge base which will be used to develop an automated process plan. The need of easy and handy method for process plan generation is addressed here. We came up with a solution that can enable any inexperienced worker to get the process plan. Also this method can be used to identify the best feasible process plan from all available options. In this chapter we are not dealing with feature extraction part. We are continuing our work assuming that we have input from feature extraction module.

9.3 Motivation Behind the Approach

During the literature survey, we came across many techniques involving knowledge base preparations and scheduling modules. In some papers, decision-making was used for scheduling. Further, SCOPUS search engine showed us that very less work has been done by using decision-making techniques in knowledge base preparation. This motivated us to prepare a knowledge base and use matrix as a device to store data regarding manufacturing processes.

9.4 Methodology Adopted for Preparing Knowledge Base

Though generative approach is mainly focussed in the area of CAPP development, in this work we are adopting hybrid approach consisting of both the generative approach and variant approach. Related to both the approaches, the concept of knowledge base and group technology will be used respectively. Group technology will be used for part family preparation and master part (consolidated by all the operations of family members) selection. Based on the operations type, parts are divided into part families. For a particular part family, its master part is defined and the various process plans for this master part are collected from experts and experienced workers. The multiple process plans serve as input to develop a frequency matrix for developing the model.

9.5 Preparing Frequency Matrix

Frequency matrix is major aspect of this approach. We are calling it as frequency matrix, since it is representing frequency of operations as stated by surveyed people. It is prepared to convert surveyed data in mathematical format such that it can easily be utilized further to decide operation precedence.

Elements in the matrix are filled using the following steps:

- If in a particular survey, process plan starts with operation 1, put 1 in frequency matrix at (1, 1) position.
- After that if process plan denotes operation 3 after operation 1, put 1 in frequency matrix at (1, 3) position.
- Do this for the entire process plan.
- Consider next process plan, fill all data entries similarly.
- If a particular cell is already filled in the matrix, add one more 1 for the new entry in that position.

After completing the matrix, if in a particular cell (for example (1, 5)), we find data as 5, we can easily say that out of all people surveyed 5 people preferred operation 5 after operation 1. By this way we can find logical consistency of every operation with respect to other operation in mathematical format. This matrix will then be used for finding out the best process plan through Multi-Criteria Decision-Making Process (MCDM) technique. MCDM technique will sort the alternatives, i.e. operations in this case, in order of their preference. Among various MCDMs, we are using TOPSIS for deciding preference order of operations in optimized process plan.

9.6 TOPSIS

Technique for order performance by similarity to ideal solution (TOPSIS) is a technique for order preference by similarity to ideal solution that maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes, whereas the negative ideal solution maximizes the cost criteria/attributes and minimizes the benefit criteria/attributes (Zavadskas et al. 2016). An MCDM problem can be concisely expressed in a matrix format, in which columns indicate attributes considered in a given problem; and rows list the competing alternatives (Ataei 2013). Major objective to use an MCDM is to find out how frequently a given operation sequence is preferred over all available operation sequences. Since this method gives results by comparing the given solution with ideal solution, hence, it will sufficiently serve the purpose (Jain and Raj 2013). Hence, TOPSIS is applied on above frequency matrix keeping weights of all of the operations as same. Results obtained from TOPSIS will give us the desired process plan for given master part.

9.7 Using Frequency Matrix as Knowledge Base

The idea of using frequency matrix as knowledge base is extended to get process plans of members of a part family. To get the process plan for a part in family, frequency matrix needs to be modified since each part does not contain all the operations that the master part contains. While applying the method, make the respective row and columns of frequency matrix zero for the operations which are not present in the given part. Again applying TOPSIS on this modified matrix will give us the process plan for that family member. This way we are using the frequency matrix as knowledge base for that part family.

9.8 An Example

Consider the following part family, which requires a total of 11 operations for the manufacturing of its family of parts as shown in Fig. 9.1.

The data from eight numbers of experienced workers were collected through survey. Feasible process plans for the above master part led us to the following data (Table 9.1).

Based on the above survey a frequency matrix is prepared following the steps as stated in Sect. 9.5 (Table 9.2).

Applying TOPSIS on the above matrix, the results are shown in Table 9.3. The operation sequence in the table is the process plan for the master part.

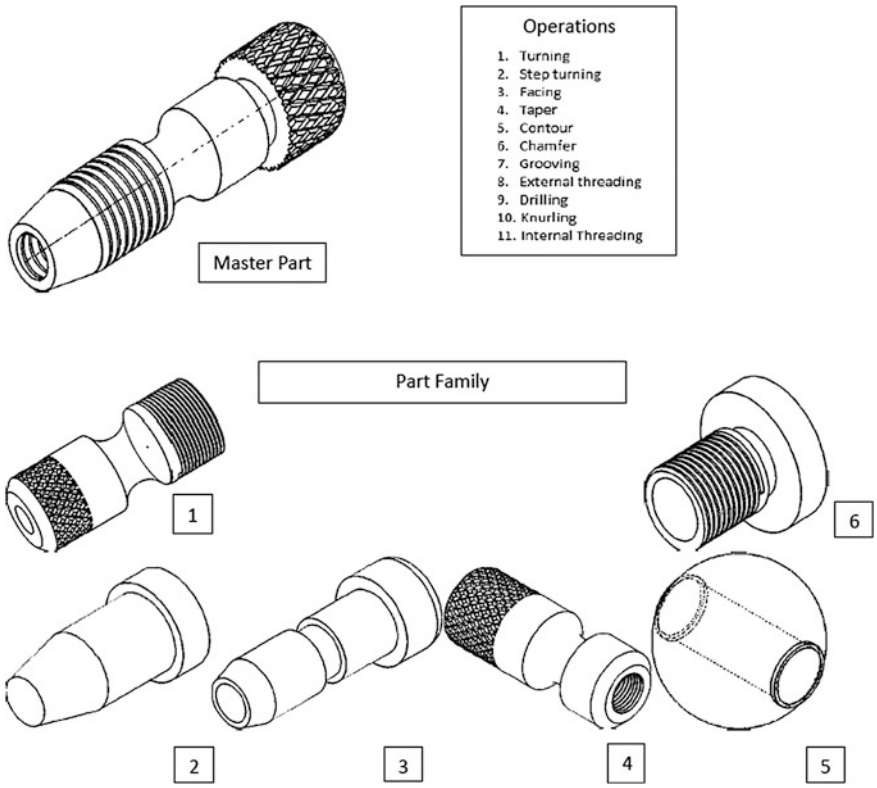

Fig. 9.1 Part family with master part

Table 9.1 Survey data of master part

S. No.	Process plan
Survey 1	3-1-7-2-4-5-10-8-9-11-6
Survey 2	3-1-2-7-5-4-10-8-9-11-6
Survey 3	1-3-6-2-7-5-4-8-9-11-10
Survey 4	1-3-6-2-7-5-4-10-8-9-11
Survey 5	1-2-3-9-11-7-5-4-8-6-10
Survey 6	3-9-11-1-2-4-5-7-8-10-6
Survey 7	1-3-9-11-6-2-7-5-4-8-10
Survey 8	1-2-3-9-5-11-4-7-8-6-10

Table 9.2 Operations precedence frequency matrix of the master part

Operation	1	2	3	4	5	6	7	8	9	10	11
1	5	4	5	0	0	0	1	0	0	0	0
2	0	0	2	2	0	0	4	0	0	0	0
3	2	0	3	0	0	2	0	0	4	0	0
4	0	0	0	0	2	0	1	3	0	2	0
5	0	0	0	5	0	0	1	0	0	1	1
6	0	3	0	0	0	0	0	0	0	2	0
7	0	1	0	0	5	0	0	2	0	0	0
8	0	0	0	0	0	2	0	0	4	2	0
9	0	0	0	0	1	0	0	0	0	0	7
10	0	0	0	0	0	1	0	3	0	0	0
11	1	0	0	0	1	3	1	0	0	1	0

Table 9.3 Result obtained from TOPSIS for the master part

Ranking of operations	TOPSIS score	Operation sequence
1	0.571408	Turning
3	0.663826	Facing
2	0.675419	Step turn
7	0.684896	Groove
5	0.687204	Contour
8	0.691408	External thread
4	0.699368	Taper
9	0.720095	Drilling
11	0.722029	Internal thread
6	0.745596	Chamfer
10	0.776415	Knurling

9.9 Analysis of the Result

The results are analysed on the basis of total machining time corresponding to a process plan. The actual operation time of all the operations will remain the same irrespective of any process plan. Differences in total machining time among various process plans will come due to idle tool movement and tool changing time in the process plans.

To calculate the idle tool movement corresponding to a process plan, we prepared the distance matrix (Table 9.4) consisting of data as distance between any two operations i and j, where $i \neq j$ considering the dimensions of the master part as shown in Fig. 9.2. Then we calculated the idle tool/carriage movement for each process plan (Table 9.5).

Table 9.4 Distance matrix of master part

Operation	1	2	3	4	5	6	7	8	9	10	11
1	0	16.5	16	16	9	1	4	13	18.5	3	18.5
2	25	0	13	13	6	2.5	1	10	15	0.5	15
3	2.5	2	0	2.5	9.5	17.5	14.5	5.5	0	15.5	0
4	3	1	3	0	4	12	9	0	5.5	10	5.5
5	25	25	10	10	0	5	3	7	12.5	3	12.5
6	16	16.5	16	16	9	0	4	13	18.5	3	18.5
7	25	11.5	11	11	6	3	0	10	16.5	1	16.5
8	25	25	7	7	0	8.5	5	0	8.5	6.5	6.5
9	7.5	7	7.5	7.5	14.5	20.5	16.5	10.5	0	17.5	5
10	25	16.5	16	16	6	25	4.5	10.5	18.5	0	18.5
11	7.5	7	7.5	7.5	14.5	20.5	16.5	10.5	25	17.5	0

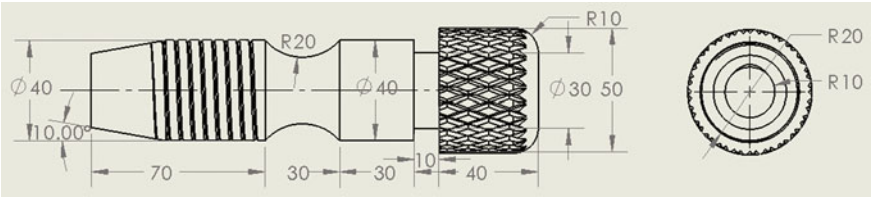

Fig. 9.2 Drawing of master part

Table 9.5 Idle tool movement factor for various process plans for the mater part

Idle tool movement	
Process plan from	Distance travelled by tool
Survey 1	82.2
Survey 2	90.2
Survey 3	97.2
Survey 4	100.7
Survey 5	78.5
Survey 6	85.5
Survey 7	81.5
Survey 8	86.4
TOPSIS	73.0

Above values tell us that idle tool movement is less in the resultant process plan obtained through TOPSIS. The reduction in idle tool movement is in favour of reducing total machining time for the given part which is the case if the resultant process plan obtained through TOPSIS is followed. Hence, for the master part we can say that resultant process plan is the best from the point of view of minimizing

Table 9.6 Process plan for each member of the part family obtained through TOPSIS

Part number	Process plan obtained through TOPSIS								
Part one	4	1	5	3	9	8	10	11	
Part two	1	2	3	4					
Part three	3	1	2	6	4	7	9		
Part four	4	1	3	5	8	9	11	10	6
Part five	3	9	5						
Part six	1	7	2	3	8	9			

idle tool movement time. After proving that the process plan obtained through TOPSIS is the best process plan, we found out the process plans of the family of parts through TOPSIS in the following section.

9.10 Applying TOPSIS Method to Find out Process Plans of Family Members

In this section, we discuss how to apply the TOPSIS approach on each member of the part family. For applying the proposed approach on a part, which is already proved to generate the best process plan when the same is identified based on the survey, check for the operations which are/are not required to manufacture that part. Make the corresponding rows and columns of those operations zero in the frequency matrix shown in Table 9.2. Then apply TOPSIS method on the resultant frequency matrix to get the process plan of that part. Table 9.6 shows the results obtained in terms of optimal process plans for each member of the part family.

All of the above results are feasible process plans. Similar to the results shown in Table 9.5 for the master part, analysis for checking the optimality of the result for the family of parts can be done by comparing the values of idle tool movement.

9.11 Conclusion

This chapter discusses a new methodology for computer-aided process planning using decision-making technique. Here, for process plan generation, generative approach is applied along with group technology. First, parts are classified into part family using group technology. Then master part for each family is prepared, which involves all the operations family members are having for their manufacturing. For the master part, we constructed a matrix denoting the frequency of operations. Process plan corresponding to the master part is generated by applying TOPSIS on the frequency matrix. The resultant process plan from TOPSIS followed the manufacturing precedence constraints. To check the acceptability of resulted process plan, the distance matrix is used to find the idle tool movement in the process

plan. TOPSIS-generated process plan has least idle tool movement as compared to other surveyed process plans. Hence, the process plan obtained from TOPSIS can be considered as the best process plan from the point of view of idle tool movement.

Once the frequency matrix is prepared for the master part, it can be used to get the process plans for the members of part family. Hence, the developed approach has been successfully applied on the members of part family which need operations on only turning machine. Frequency matrix thus serves as an efficient knowledge base for a particular part family.

The TOPSIS approach proposed here is an easy and low-cost approach. It enables to find the preferred operations precedence for a particular part if the acceptable process plans are provided for that part (in the form of survey). The method is also giving us the best probable operation sequence among all available operation sequences. Hence, any inexperienced worker can use this method to get the best process plan if he has opinions of various experts.

Although our developed KBS gives the feasible process plan, matrix filling strategy applied here can be changed with new logic and other MCDMs can also be used to decide the hierarchy of operations. There are other aspects besides idle tool movement on the basis of which optimality of the process plan can be checked. Also process plan preparation for parts with repeating operations (e.g. parts with multiple step turning operations) is not addressed in the chapter. Hence, there is a scope for further research and improvements in that direction.

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Chapter 10
Analyzing the Role of Management of Technology in the Growth of Technology Ventures

Sachin Salian, Anup Bali, V. Yugandhar and Kirankumar S. Momaya

10.1 Introduction

The future is being created by technology entrepreneurs. The number of instances of ventures getting funding from venture capitalists and angel investors is proof of that Engineering institutes have a big part to play in such a time as every year many startups arise from these institutes, get incubated, and graduate in a few years span. The environment within the top engineering institutes also promotes technology entrepreneurship. In this chapter, the authors have attempted a case-based research on two ventures that have emerged out of IIT Bombay. The authors attempt to realize the important factors related to management of technology, which affect the growth of technology ventures.

Management of Technology has been defined by the U.S. National Research Council as "the engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organization" (U.S. National Research Council 1987).

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Management of technology consists of a few factors such as a technology strategy, technology forecasting, i.e., identifying technologies which the organization can use in the future, technology road map, i.e., connecting technology with businesses and market needs, technology process and product portfolio, i.e., technology in development.

Steps involved in management of technology include

1. Choice of technology—shortlisting a list of technologies which the business can use for its product.
2. Identification—choosing a technology for your business among many available alternatives.
3. Product development and commercialization—measuring and optimizing product development life cycle.
4. Technology up-gradation and transition—incremental updates and overhaul of technology to next-generation technology for competitive advantage in the market and to provide the best quality products (Council U.N. 1987).

Venture scale-up is defined as the growth of the firm in one or multiple attributes such as sales (number of products sold), revenue, geographic spread, number of employees, etc. By exploring these aspects of Management of Technology, we can understand the importance and impact of each of these on the short-term and long-term growth of the venture.

10.2 Literature Review

10.2.1 Venture Growth

Growth of a venture is an important measure of the performance of the venture (Candida and Pieter 1992; Gaylen and Steven 1994). So far researchers have defined many factors related to growth and measurement. Venture scale-up has been defined in terms of employee scale-up, revenue scale-up, and profit scale-up (Robert and Robert 1990; Tone and Sue 1996; Don and Eric 2001; Edwin and Ken 2001; Mehta et al. 2014). In lieu of the above work, all throughout the chapter, venture scale-up has been measured in terms of revenue scale-up and employee scale-up as used in the recent work (Mehta et al. 2014).

Growth is the life cycle stage in which the firm experiences an almost consistent state of change having the owner in the central part of the system. High-quality maintenance, establishing market share, managing personnel, the requirement of professionally trained and experienced personnel and scaling technical and manufacturing capabilities are the key problems to be faced in this stage (Robert and Robert 1990).

10.2.2 Role of Management of Technology in Venture Growth

Shaker and William (1999) highlighted five key dimensions of technology strategy which have the impact on ventures performance. Five key dimensions described from the literature are: Radical product innovation, intensive new product upgrades, R&D spending, the use of external resources, and the use of copyrights and other means of intellectual capital protection. Radical product innovation plays an important role in the growth stage of industry life cycle by providing competitive advantage and market success. Companies undergo major technological changes during this growth stage.

In all type of ventures, technological strategy is an important characteristic in improving new venture performance. Intensive R&D investment from both internal and external R&D sources along with frequent product introductions and patenting were positively correlated with corporate venture performance (Shaker 1996). Growth in the early stages of a venture has been seen as coming essentially from internal sources, particularly internal R&D applied to product enhancements and extensions (De 1977; Lazer and Shaw 1986). As ventures move toward commercialization their financial needs grew exponentially and an urgent need to scale-up funding for seed stage was identified for Indian ventures (Momaya and Bardeja 2005). The follow-up work also reinforced the need for better cooperative strategies for innovation (Momaya 2008).

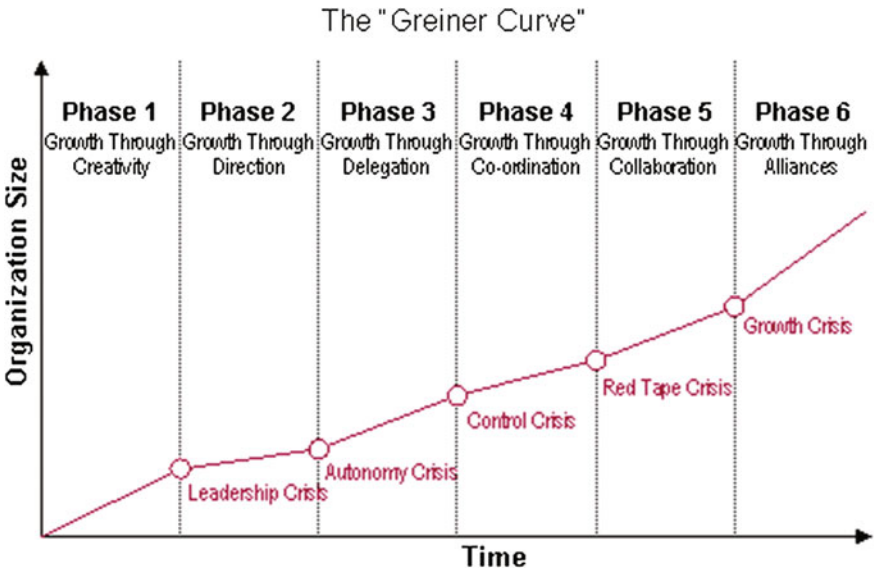

Fig. 10.1 Greiner curve of growth and crisis. *Source* Greiner (1972). *Evolution and revolution as organizations grow*. Harvard Business Review

A new venture undergoes 5 distinct stages during its business life: Existence, Survival, Success, Take off, and Maturity (Churchill and Lewis 1983). Our focus has been to study firms in the Success and Take off stages of the business life. In each of these stages the firms face different kinds of hindrances in scaling up, ventures in the success and take off stage face crisis of control (Greiner 1972). Figure 10.1 shows the different stages of a venture lifecycle with the crisis faced at each stage.

10.3 Methodology

The initial phase involved extensive literature review which answered a few of key questions, i.e., in which stages do ventures stagnate and what crisis do they face at each stage. The study has been focused on ventures which are between 8 and 12 years old, ideally in the take off and success stage of their life cycle. Also only technology product ventures have been studied as the management of technology features would be more prominent in such firms.

The authors ideally wanted to compare two firms which showed a few contrasting attributes. In that endeavor the authors tabulated and plotted a list of 9 ventures based on a few characteristics (Appendix 1).

X axis: Employee Scale-up—No. of employees added per year
Y axis: Age of the company during the first investment
Radius of Bubble: Age of the company.

By doing this exercise the authors were able to clearly identify two firms which were around 8–11 years old and were showing contrasts in terms of employee scale-up. SEDEMAC and Webaroo both received investments early in their life cycles. Webaroo was able to show a larger employee scale-up compared to SEDEMAC (see Fig. 10.2).

After selecting the two firms, SEDEMAC Mechatronics Pvt. Ltd and Webaroo, the authors set out to identify management of technology characteristics of each firm and explore the contribution of these factors to their growth over the years.

In earlier works on technology management, researchers conducted exhaustive interviews with firms to shortlist the essential attributes and factors of technology management which catalyze growth and performance of the firm (Sahlman and Haapasalo 2012). A similar approach was adopted for this study. Interviews were conducted with the top management of both the firms which highlighted a lot of insights regarding their performance, strategic decisions, and future plans. To support the primary research, a secondary research was conducted on these companies to gain additional information such as rounds of funding, amount of funding

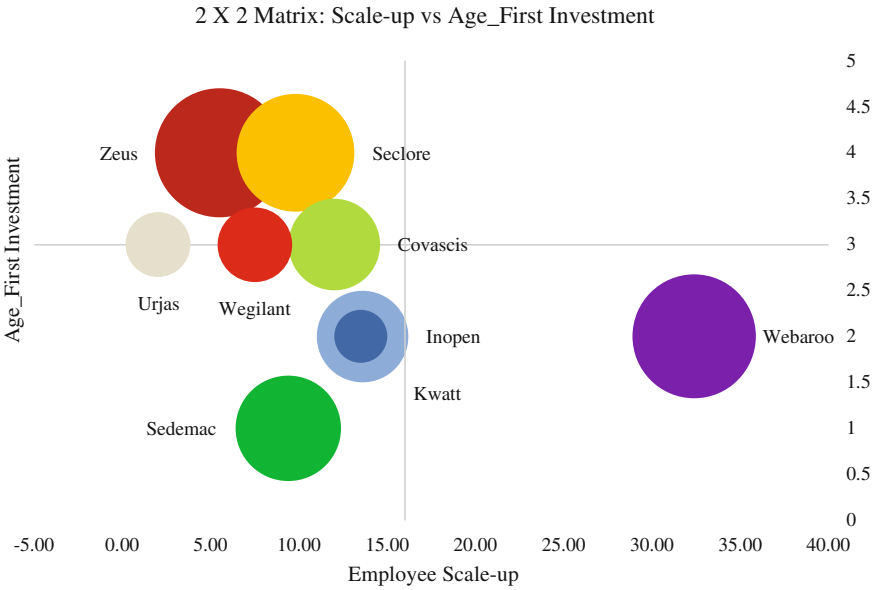

Fig. 10.2 An example of typology used for analysis of venture scale-up and selection of firms for cases. *Source* Developed based on data collected from secondary sources; details are given in the Appendix 1

from sources such as startup databases, news articles, etc. After obtaining the required information, the data was tabulated and compared to showcase useful contrasts.

10.4 Analysis

10.4.1 SEDEMAC Mechatronics

The firm produces engine control units that reduce fuel consumption and cut down on emissions. They serve nine major Original Equipment Manufacturers (OEMs) in India such as Mahindra, Tata Motors, Kirloskar, TVS Motor Company, Bajaj Auto and a few more in 2015. They also plan to expand to Africa by providing diesel engine control units for telecom towers which consume a lot of fuel. SEDEMAC management believes in upgrading technology; which is visible by looking at the number of patents that they have filed and the number of patents they are currently working on. They have a dedicated sales team which approaches OEMs for different product offerings. Their year-on-year revenue has been doubling over the past three years (2013–2015), which is due to the open order contracts which they

have signed with different OEMs. Also the future trend in automobiles is to introduce electronics into engines. Keeping this in mind SEDEMAC's microprocessor-controlled engine control units are a perfect fit. SEDEMAC continuously upgrades its products and makes significant changes with the generation that come in engines. SEDEMAC management does not believe in getting into strategic alliances to scale its business. The management of SEDEMAC believes that they are trendsetters in the industry and presently do not have any competition from an Indian counterpart.

10.4.2 Webaroo Technologies

Webaroo is a software-based company and the products offered are those of communication-based applications for system and mobile phone devices. They provide SMS, data, voice, email, and USD-based services. The suppliers for the company are all telecom network companies. The customers range from 200 large companies to 20,000 medium and small-sized firms. The cost incurred is kept to minimum with the use of open-source software technologies in software. The company has an Early Starter advantage with just one major competitor serving in the same space. The company is headquartered at the US with all resource allocations from India. The company has been able to spread itself across the industry with partners such as Mphasis, TCS, Infosys, and other IT companies. The applications offered by the firm are Gupshup and TeamChat. TeamChat enables enterprises use its existing technological framework to build a chat-based application for quick and easy communication. Gupshup is a Cloud-based chat application. The company believes in propagating the product using Sales and Marketing methods with minimized focus on the technological up-gradation. The company is currently more than a decade old and shows consistent increase in growth in revenue posting a 50% growth last financial year. The firm has its presence in Mumbai, New Delhi, Bangalore, and Chennai. The firm aims to continue being the market leader in the space and serving greater number of clients.

Based on the insights shared during interviews with the top management of the ventures the authors were able to generate an approximate revenue scale-up model (Refer Appendix 2).

Figure 10.3 shows a striking contrast in terms of revenue scale-up, but both firms have shown good year-on-year growth rates in their respective industries. Our interviews revealed many technology related insights as shown in Tables 10.1, 10.2 and 10.3.

Webaroo has greater number of employees; the concentration is greater in Sales and Marketing of the products. Both SEDEMAC and Webaroo have a large R&D team with respect to the total number of employees in each. Webaroo was able to receive a lot more funding than SEDEMAC and this may have contributed to its

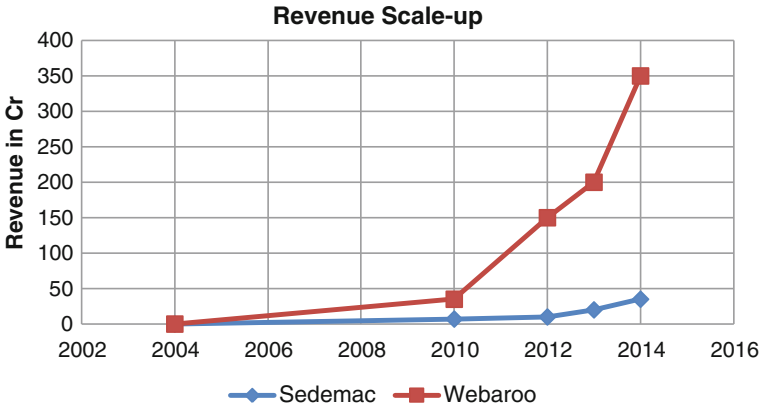

Fig. 10.3 Differing trajectories of revenue scale-up in the two ventures. *Source* Data from interviews

Table 10.1 Comparative view of select input factors

S. No.	Factors	SEDEMAC	Webaroo
1	R&D team size	Total—60; 10 in concept design 50 in product design	80
2	No. of rounds of funding	2; Seed—2008, Series A—2010	5; Series B—2006 $10m, Series C—2008 $11m, Series D—2010 $12m, 2011 $10m
3	Time from last round of funding	5 Years	4 years
4	No. of employees	105	175
5	Age of firm (years)	8	11

Comments SEDEMAC Mechatronics has 60 people in Product development; with electronic hardware, embedded software and application as divisions, having approximately equal number of employees in each division. SEDEMAC received two major funding, receiving smaller amounts in between; Webaroo has had higher funding over the years

rapid scale-up. Webaroo provides sales and service support to its clients unlike SEDEMAC hence they have a large product support team.

Suppliers for Webaroo are fixed—telecom operators. Competitors are very few for SEDEMAC Mechatronics, has early mover advantage; they refer to themselves as trendsetters. Technology does not seem to play a major role for Webaroo in comparison with SEDEMAC Mechatronics. The updates are specific to requirements for both firms. SEDEMAC has clearly defined distinct core competencies.

Table 10.2 A quick comparative view of select factors in two ventures

S. No.	Factors	SEDEMAC	Webaroo
1	No. of products being worked on	3 product families; might be developed in 3–6 months	No products being developed; only product support services are being provided
2	Suppliers	5	~10
3	Competitors	2; Woodward and deepsea electronics	1 main rival, several small companies
4	Frequency of technology up-gradation	3–4 years with change in generation of engine; minor improvements are made continuously	Requirement based
5	Core competencies	Reliable products, understanding of physics of system, manufacturing, software skill	Service, flexibility, software skill
6	Any strategic alliances	None	With vendors such as TCS, Infosys, Mphasis etc.

Comments SEDEMAC Mechatronics caters to two markets; off highway automobiles and 2/3 wheelers. Based on this, they have categorized their products on the basis of function called product families. One product family contains many products

10.5 Results and Discussion

The data received from SEDEMAC shows that the management understands the importance of management of technology. Their activities such as presence of a structured R&D team, past and ongoing focus on building patents, up-gradation of existing products with changing technology are some aspects of management of technology (MoT) that SEDEMAC continuously focuses on. Past 3 years, the firm has witnessed 100% growth on 'year on year' sales revenue. This can be attributed to the products that they have developed for their clients. In the case of SEDEMAC, their emphasis on MoT has been able to help them scale-up. And since they are currently developing new patents and products, SEDEMAC seems to have charted out a technology road map which could help the firm grow further in the future. The success of SEDEMAC can be partly attributed to their continuous focus on MoT.

Webaroo has been able to reach revenue of around 350 crores within 11 years of operation. They have only two products, but have an installed base of more than 200 clients. Over the years, Webaroo has not focused on new product development, but rather has invested in developing a competent sales and support team. This team is able to provide licensing, customization, consulting, and up-gradation services. Their work force is able to provide sales and service support to their entire client base. The emphasis of Webaroo on sales and marketing of its products has been a critical factor in its scale-up. Webaroo has harnessed the technology capabilities and technology knowledge of their employees to provide the best-in-class service in the enterprise and mobile communication product segment.

Table 10.3 Glimpse of comparative performance on MoT-related factors

S. No.	Factors	SEDEMAC	Webaroo
1	Avg. time required for NPD	18 months	3 months
2	No. of patents filed Internationally	3	0
3	No. of patents filed in India	2	0
4	No. of Intl. patents being worked currently	0	1
5	No. of Ind. patents being worked currently	4	0
6	No. of Indian clients	9; all major automobile OEMs of the country	200 medium and big sized companies 20,000 small customers
7	Growth rate	100% for last 3 years; last 3 years the revenue has been doubling	Last year 50% YoY
8	Services provided	Only after sales support and investigation of product failure service is provided, quality control team decides changes after customer feedback	Heavy focus on service; customization and changes as per customer request big team to handle growing service request

Comments Since SEDEMAC Mechatronics involves manufacturing, producing a new product will take more time compared to Webaroo which produces communication applications. SEDEMAC Mechatronics has much greater number of patents. SEDEMAC Mechatronics focuses a lot on technology with 60 member R&D team, as mentioned earlier. Webaroo has a greater number of clients but based on the size of the clients, the revenue earned varies to a large extent. Both companies are growing fast in their respective industries

The comparative case analysis provides rich insights about factors of competitiveness in early stages of venture and contrasts in approaches to MoT. Marketing related ventures may be needed for 'born global' type of pathway. Webaroo seems to pursue. In contrast, SEDEMAC seems to focus more on technological factors to address a vexing global problem related to engines and powertrains by building control solutions that enable realization of best-in-class fuel efficiency and/or emissions and/or power delivery in applications involving small engines. Such sharper focus may not give them faster scale-up in near future, but it can help evolve a better ecosystem for technological competitiveness (Mittal et al. 2016).

The ventures should learn about 'inflexibility of technology' (Sushil 2016) and minimize it. Cooperative strategies among many such ventures is needed to evolve cluster with high technological competitiveness (Momaya 2008), and is an area of high interest in Group on Competitiveness at IIT Bombay.

10.6 Conclusion

By studying data of both the firms it is clear that the firms have focused on different factors in order to strengthen their growth. Management of Technology differs for different industries; for manufacturing firms it depends upon effectively managing product technologies, but for IT firms, Management of Technology involves managing process technologies and harnessing the software capabilities of employees. So when seen from hindsight the success so far of both the firms has been through the good utilization of their technological capabilities. For a firm to be successful, it needs to identify, understand, and utilize its technological competitiveness more effectively. The performance of the two firms taken up in the study reinforces the importance of Management of Technology for a growing technology venture.

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Appendix 1: Basic Data Related to IITB Ventures

See Table 10.4.

Employee Scale-up was calculated as difference between number of employees during year of count upon difference between age of count and year started.

See Table 10.5.

Table 10.4 View of the range of employee scale-up for select IITB incubated ventures

S. No	Name of the company	Industry	Year started	Age of the firm	Employees			Jump	Appro. employee scale—up
					Initial	Count	Year		
1	Zeus Numerix	Software	2003	12	4	42	2010	38	5.5
2	Webaroo	Software	2004	11	3	100	2007	97	32.4
3	Seclore	Software	2005	10	2	80	2013	78	9.8
4	SEDEMAC	Mechatronics	2007	8	4	60	2013	56	9.4
5	Covascis	Software	2009	6	2	62	2014	60	12
6	In open	Education	2009	6	3	71	2014	68	13.6
7	Wegilant	Software	2011	4	1	16	2013	15	7.5
8	Urjas	Renewable energy	2012	3	2	8	2015	6	2
9	Kwatt solution	Renewable energy	2013	2	3	30	2015	27	13.5

Source Based on interviews with venture employees and venture websites

Table 10.5 Differences in revenue scale-up time line

Year	SEDEMAC revenue in Cr.	Webaroo revenue in Cr.
2004	0	0
2010	7	35
2012	10	150
2013	20	200
2014	35	350

Source Data obtained from interview with firm's management

Appendix 2: Interview Guide Questions

Parameters in management of technology

1. Technology choice
   (i) How was the technology chosen? What factors were considered while choosing the technology?
   (ii) Any plans to change the technology? On what basis will the technology be changed?
2. Identification
   Why did you select this technology?
3. Absorptive capacity: firms ability to recognize, assimilate, and utilize the technology
   When did you obtain the technology? How fast were you able to produce your first product?

4. Network externalities: value of good increases with number of users
   If the number of customers increases does that have any impact on the value of your product?
5. Installed base = No. of customers
   How many clients do you currently serve?
   During the first round of funding how many clients did you have?
   What is the average growth rate in number of clients?
6. Complementary goods/service being provided
   Do you provide any auxiliary product/service along with the main product to your clients?
7. Suppliers
   How any suppliers do you have for your raw material?
8. Vertical integration; buying out suppliers or distributers
   Since graduation have you been able to make any significant acquisition in your distributor/supplier network
9. Presence of competitors
   How many competitors are there in your market serving the similar target group?
10. Customer Feedback
    Do you have a pilot/focus group to test your product?
    After releasing the product have you incorporated any changes as suggested by the clients?
    Do you customize products as per customers' requirements using their feedback?
11. Entry barriers to your business
    What are the entry barriers to your business?
    Is your value offering easily imitable by competitors?
12. Tacit resources—those resources which we can't measure
    Can you give us an account of the technical and business expertise of your employees?
13. Core competency
    What would you call the core competency of your firm?
    What differentiates your product form the products in the market?
14. Parallel process development
    Do you have parallel process development for manufacturing your product?
15. R&D Intensity = ratio of amount spent on R&D investment/amount of sales
    What is the R&D Intensity of the firm?
16. Any collaboration strategies—alliance, joint venture, licensing, capability complementation, capability transfer, contract manufacturing
    Do you have in mind any collaborative strategy for your product with respect to your peers?
17. Patents
    No. of patents applied for in India and internationally, no. of patents granted
    Organizing for innovation

18. Formalized structure—utilizing rules, procedures to structure behavior of individuals
    (i) Mechanistic—high degree of formalization, operations are automatic/mechanical
    (ii) Organic—low degree of formalization, jobs are not well defined, variable operations

    Is your venture mechanistic or organic?
    Offshore strategies
    Center for global strategy—all innovation activities are at a central hub then diffused
    Local for local strategy—each location executes individual R&D for local market
    Locally leveraged strategy—each location executes individual R&D for/r global market
    Globally linked strategy—decentralized R&D, leveraged globally
    Which among the top strategies have you adopted for your venture?
19. Managing NPD process
    Development cycle time–time from project initiation to project launch
    How much time does it require you to design a product from idea to production phase?
20. Employee
    How many employees do you have? What is their technical background?
    What are their roles? How long have they been working with the firm?
21. Compatibility
    Compatibility of the product with systems across generations—present, future, and past
22. Timing of entry into market—first movers, early flowers, late entrants, open source or proprietary, purchase or develop in house
    Did you move into the market keeping the business age of the venture or since the time was right?
23. Tech up-gradation
    How often do you upgrade your technology? How often do you upgrade the products?
    How often does the technology change in the industry?
24. Transition to next generation, entirely different
    Have there been any major software changes with respect to technology?
25. Product develop and commercialization
    How many products have you released? How many are currently being worked?
26. What is your YoY revenue?
    What cap of revenue have you broken in which year?

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Part IV
Financial and Risk Management

Chapter 11
Financial Flexibility Through Share Repurchases: Evidence from India

Sadaf Anwar, Shveta Singh and P.K. Jain

11.1 Introduction

Adaptation to changing business situations in the context of environmental changes and competition is the need of the hour for the business organizations. Such changes exert pressure at the top level with respect to the trade-off between maintaining desired profitability and commitment towards shareholder value maximization. This win-win situation can be achieved through 'flexibility', which is supposed to be the base of flexible systems management. "Flexibility is a multi-dimensional concept demanding agility and versatility: associated with change, innovation, and novelty: coupled with robustness and resilience, implying stability, sustainable advantage, and capabilities that may evolve over time" (Sushil 1997, 2015, 2017). In fact, in the context of financial re-engineering Sushil (1997) has emphasized on flexible managerial approach through long-term financial planning and ability to adapt to the changing business environment. Thus, the term 'financial flexibility' refers to the ability of the firm to respond efficiently to avoid financial distress during inadequate negative cash flows and unexpected investment opportunities (Gamba and Triantis 2008).

Financial flexibility drives corporate financial decisions. It offers benefits to the firm by generating internal capital reserves and smooth access to share markets. Also investors appreciate rationality to financial flexibility related decisions, due to their greater value for CFOs and positive impact on firm performance

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(Graham and Harvey 2001). Empirical evidence suggests that firms can attain this flexibility through cash management, capital structure, and payout policies (DeAngelo and DeAngelo 2007; Marchica and Mura 2010; Denis 2011; Denis and McKeon 2012). In particular, share repurchases have emerged as an effective capital management tool and represent the largest form of payout. They are being used as a signaling mechanism by firms indicating bright signal future earnings prospects.

The purpose of this chapter is to explore financial flexibility through share repurchase announcements of BSE 500 index firms listed on the Bombay Stock Exchange for the period of 10 years (2003–2013). This is perhaps a unique study of share repurchases in the context of financial flexibility in the Indian capital market. Thus, the chapter contributes to the limited research in this area.

For better exposition, this chapter has been divided into seven sections: Sect. 11.1 contains the introduction. Section 11.2 contains the review of literature and empirical framework. Section 11.3 describes the motivation and the research gaps. Section 11.4 contains the objectives and the related hypotheses. Section 11.5 consists of research methodology and Sect. 11.6 analyses the results. Further, last Sect. 11.7 contains the concluding observations and suggests implications and recommendations.

11.2 Review of Literature

This section aims at reviewing literature on how the companies' payout policies have gradually changed with time. Companies have been moving from dividends to share repurchases due to the financial flexibility inherent in share repurchase programs. Further, it presents the present state of share repurchases in the Indian financial market.

11.2.1 Capital Allocation and Payout Policy

The corporate distribution policy is considered as a critical decision of choosing between making dividend payments or retaining earnings in the company. The firms are expected to choose payout policies which can meet unexpected periods of insufficient resources. The payout policy constitutes an integral part of corporate financial decision making; it is expected to confirm to the expectations of market participants. The quest to effectively manage the payout behavior of firms has been considered as one of the challenges for the finance managers. A plethora of literature available suggests that corporate payout policy indicates bright future prospects of the firm (Bhattacharya 1979; Miller and Rock 1985). Generally, a firm has two capital allocation possibilities: it may invest in the operating business or return excess cash to the shareholders. Available cash is to be used in profitable investments where the growth opportunities have a positive net present value. The

company's cash for which no such investment opportunities can be identified (excess cash) is desired to be returned to the shareholders via cash dividend and/or share repurchases. Cash dividends meet the liquidity requisition of the investor and have vital information content as to its announcement. Share repurchases, on the other hand, are an alternative method to pay cash dividends. They lessen the equity shares outstanding in the market. Given, no change in corporate earnings and price-earning ratio, share repurchase would result in higher EPS and higher market price of a share. In fact, the decision to retain, reinvest or pay out after tax earnings in the form of cash dividend or share repurchase is important for the realization of the corporate goal which is the maximization of the value of the firm.

11.2.2 Financial Flexibility Through Share Repurchases

Historically, cash dividends are the most important form of payout policy; they have been losing popularity relative to share repurchase during the past decade (2000–2010). Traditionally, finance has focused on the theory of dividend policy as a method of delivering value to shareholders. Payout decisions, however, no longer pertain only to dividends. Fama and French (2001) proposed the 'dividend disappearing' puzzle, which describes the reduction in dividend payment by firms in recent years. Similarly, a similar observation has been stated by Brav et al. (2005) wherein the frequency of payouts through dividends has declined; likewise, Grullon and Michaely (2002) and Ridder (2009) noted that the number of share repurchases had increased. The percentage of firms paying cash dividends has declined from 66.5 (in 1978) to 20.7 (in 1998). Grullon and Ikenberry (2000) found that during the 5-year period from 1995 to 1999, companies in the U.S. announced repurchases close to the tune of $750 billion worth of stock. During the same time frame, they also observed that more cash flows were being distributed to investors by repurchases than by dividends.

Share repurchases are becoming an important channel for firms (as compared to dividends) to distribute cash to shareholders. During the last 10 years (2003–2013), share repurchases have become increasingly common around the world. In fact, empirical evidences by Grullon and Michaely (2002), Skinner (2008) and Farre et al. (2014) reported repurchases as the largest and dominant form of payout. Such an accelerated growth in repurchase activity has also been reported by Skinner (2008) from his empirical evidence "that repurchases have become the dominant form of payout".

In fact, such is the popularity of shares repurchases, that it has generated debate in the literature with regard to share repurchases as instruments of financial flexibility compared to dividends. There are many potential reasons why firms might wish to purchase their own stock. The benefits of personal tax considerations are associated more with share repurchases than with dividends (Baker et al. 2003; Hsieh and Wang 2008; Grullon et al. 2011). Other benefits include: repurchases are used to dispense temporary cash flows, share price movements, excessive cash on

the balance sheet, etc. are associated with repurchases; whereas, life cycle factors such as profitability, maturity, size, leverage and reduced investment opportunities favor dividends (Jagannathan et al. 2000; Dittmar and Dittmar 2002; Grullon and Michaely 2002; Brav et al. 2005; Skinner 2008; Coulton and Ruddock 2011).

Dividends are generally visualized as positive signals from the management and both the companies and shareholders prefer a stable dividend policy. It is only when the company has extraordinary excess earnings that it prefers share repurchases. Thus, the company and the stakeholders can avoid expectations that this extraordinary payment will be regularly repeated (Gurgul and Majdosz 2005). Also Bartov et al. (1998) have concluded that shares repurchase are a preferred option only when these are highly undervalued. Denis (1990) indicated dividend payments as means to increase the wealth of target firm shareholders of the target firm as compared to repurchases. On the other hand, share repurchases are viewed as instruments of takeover defense (Grullon and Ikenberry 2000). Brennan and Thakor (1990) documented that small distribution firms preferred dividends while large firms favoured share repurchases. It appears that the pivot point of discussion revolves around Black (1976) proposition of repurchases' tax advantage relative to dividends. In fact, by choosing share repurchase as a payout mechanism, firms minimize the tax burden of their investors (Grullon et al. 2011).

The reasons for aggressive growth in share repurchases are also due to weakening economy, decline in prices of stocks and the debt crisis in Europe. In fact, the increasing effect of this phenomenon was reflected in Standard and Poor's 500 Index companies which repurchased about $200 billion of their stocks during the first half of 2011 (Friedman et al. 2011). The amount of share repurchases rose to an annual rate of $500 billion which was almost double the rate of traditional cash dividends (Baldwin 2012). Recently, Warren Buffett, in a bid to step up the share repurchase program, repurchased up to 15% of Berkshire Hathaway's $150 billion market capitalization (Lenzer 2011; Arends 2012). Monsanto recently authorized a three-year share repurchase program totaling $1 billion. Many chemical companies had returned more than 60% of their cash reserve to their shareholders via share repurchases (Valk 2012). Apple repurchased its own shares costing $10 billion in 2013 (Moren 2012). IBM also announced a share repurchase of about $11.70 billion in the year 2013 (Savitz 2012). Further, Exxon repurchased $13.10 billion of its own shares, followed by a consecutive buyback of $18.20 billion in the first half of 2008 (Doesey 2009). Similarly, Microsoft announced that it would buyback $40 billion of its own stock between 2008 and 2013. Hewlett Packard announced that it would buy $8 billion of its own shares (Dreyfuss 2008).

According to Fried (2007), nearly 630 companies had announced share buyback worth $369 billion in the financial year 2007; the biggest being the repurchase of $30 billion shares by Proctor and Gamble. In fact, it is informative to note that from 2004 to 2008, companies have spent about cash $1.80 trillion in their share repurchase activities in the US alone (Cendrowski 2011). Grullon and Ikenberry (2000) documented that firms started embracing the share repurchase programs intensively in the 1980s and 1998 for the first time in U.S. history.

Literature cites 'flexibility' as the probable reason for the expansion of repurchase activity compared to dividends (Brav et al. 2005; Baba and Ueno 2008). Thus, this chapter attempts to examine the extent of the use and the underlying reasons behind firms' choice of financial flexibility, through share repurchases. It would also investigate the returns (if any), accruing to the shareholders of sample companies on the announcement of share repurchases.

11.2.3 Empirical Framework

11.2.3.1 Share Repurchases in India

U.S. has the oldest history of share repurchases. They were introduced in the U.S. in the late 1960s, and had become popular by mid-1980s. India recognized the usefulness of the share buyback system in late 1998. Share repurchase by companies in India are regulated by Sections 77A, 77AA and 77B of the Companies Act 2013, SEBI (Buyback of Securities) Regulations, originally framed in 1998 (latest Securities and Exchange Board of India (Buyback of Securities) (Amendment) Regulations, 2013).

The important provisions relating to repurchase of shares include special resolution in annual general meeting and financing from securities premium or free reserves or from the proceeds of earlier issue of dissimilar shares. Further, the buyback has to be allowed under the Articles of Association. The buyback should not exceed beyond 25% of the paid up capital of the company in a year. The debt equity ratio should be within the range of 2:1. Two buyback programs should have time interval of 12 months even if they are for dissimilar securities. According to the latest SEBI norms, the companies are being asked to keep 25% of the planned buyback offer amount in an escrow account. This has been done to prevent companies to wrongly inflate the share prices. It is also mandatory for companies to repurchase a minimum of 50% shares of the total targeted share repurchase amount. There will be a penalty of a maximum of 2.5% on the funds lying in the escrow account (in case companies do not adhere to regulations). The share repurchase activity was not popular in India since its introduction in 1998. Table 11.1 shows the growth in share repurchases in India.

It is observed from Table 11.1 that the number of companies announcing share repurchases in a year has not even reached the figure of 70 till 2008 (except for the three years, 2001–2003). Rather, the number of share repurchases has diminished after the year 2002–2003. With a fall in number of announcements after 2003, the next crest is visible around 2008–2009 when the number of announcements have reached unprecedented levels of 59. Thus, the year of sub-prime crisis in USA has evoked the response with large number of buyback undertaken in that year in India. The probable reason for such an increase could be undervaluation of shares. The fall in share prices of the sample companies (at the time of American financial crisis) sitting on substantial reserves might have induced the companies to

Table 11.1 Share repurchase activity during 2000–2014

Year	No. of share repurchases	Year	No. of share repurchases
2000	11	2007	19
2001	45	2008	59
2002	69	2009	42
2003	31	2010	19
2004	18	2011	31
2005	15	2012	24
2006	10	2013	25
		2014	32

Note This table displays year-wise distribution of share repurchase announcements compiled from BSE and SEBI website

Table 11.2 Shares repurchase activity at five year high in 2013–2014

Year	Number of offers	Offer amount (Rs. Crore)	Acquired amount (Rs. Crore)	Percentage (%)
2008–2009	19	1,891	1,763	93
2009–2010	44	4,146	1,192	29
2010–2011	23	4,181	4,008	96
2011–2012	19	2,582	1,152	45
2012–2013	26	12,532	4,746	38
2013–2014	31	5,704	4,426	78

Note This table depicts the hare repurchase activity from 2008 to 2014. *Source* http://www.thehindubusinessline.com/

restructure themselves through financial flexibility. Thus, share repurchases, could be undertaken to provide temporary jumps in share prices; providing a good solution for the Indian companies in times of financial distress. Although stability in prices has reduced the number of announcements after 2008, yet strong financial motivations have persuaded companies to utilize more and more funds through share repurchases.

The Indian companies have been witnessing a large cash build-up. The average cash reserves with the BSE Sensex indexed companies have increased from Rs. 325.70 crore to Rs. 6000 crore, a staggering compound annual growth rate of 38.2% during 2005–2013 (Source: Business World Website 2015). Reliance Industries launched the India's largest ever share repurchase program in January, 2011. Likewise, many other companies like Zee Entertainment, Amtek Auto, Gemini Communication, JK Lakshmi Cement, Monnet Ispat, Kirloskar Engines, etc. have also launched the repurchase program. The Indian companies seem prefer share repurchases as a method of rewarding shareholders as compared to dividends. Table 11.2 shows high share repurchase activity over the past years (2008–2013).

Hence, it is important to study the event of share repurchase from the perspective of financial flexibility in terms of returns it generates to the shareholders. This move

also leads to an increase in promoter holding. An analysis on these lines would throw light on the behaviour of share repurchases and the influencing factors of payout policy.

11.2.3.2 Major Hypotheses

A share repurchase is viewed as microcosm of corporate finance. Some of the well-known hypotheses available in the literature to describe the rationale for share repurchases are briefly discussed below.

Signaling Hypothesis suggests that companies use share repurchases to convey to the market positive information about the firm's future prospects. They signal to the firm that the existing share prices are below the intrinsic value of shares (Jagannathan and Stephens 2003).

Tax Motivated Substitution Hypothesis is based on the difference in tax treatment associated with capital gains (due to change in share prices) and cash received due to current dividend payment (Hsieh and Wang 2008).

Dividend Substitution Hypothesis suggests that share repurchases are becoming an important channel for firms to distribute cash to shareholders as compared to dividends and that the firms are substituting dividends by repurchases (Grullon and Michaely 2002).

Capital Structure Adjustment Hypothesis suggests that as companies repurchase their stock, the equity base contracts and debt/equity ratio increases. It appears that share repurchases are a tool for obtaining the optimal capital structure (Chan et al. 2000).

Price-Enhancing Effect Hypothesis suggests that share repurchase results in the availability of lesser number of shares in the market. This leads to increase in the earnings per share as well as the market price of the shares (Cesari et al. 2011).

11.3 Motivation for the Study

The Indian economy is becoming a hub of more inclusive economic growth. The Indian stock market has become an important intermediary between issuers, analysts and investors both at the local and international level to conduct financial transactions. In India, stock repurchases were introduced in 1998; however, they gained momentum (but not at a desired level) from 2002 to 2003 onwards. Moreover, the research in the Indian repurchase context assumes significance for several reasons as documented by Agarwalla et al. (2014).

An important element of the repurchase environment in India relates to disclosure of repurchase activity by the firms on daily basis compared to U.S. market where it is required only on a monthly basis. This leads to significant cost to execute open market repurchases in India. In fact, the higher cost might indicate that shares

repurchase is a more reliable indicator of undervaluation in India as compared to other markets.

The Indian regulations do not allow promoters to tender their shares during open market repurchases. This can highlight the greater signaling effect of the share repurchase announcements.

There is a huge information asymmetry between insiders and outsiders of firms. Hence, the chapter brings into light the influence of the above factors on the stock market as well as on the share repurchases motives of the Indian companies. As per the authors' knowledge, this is the first empirical study (in-depth) on the impact of financial flexibility through share repurchases decisions.

11.4 Objectives and Research Hypotheses

Since companies in developed countries like U.S. are commonly involved in share repurchase, this chapter would contribute to the economic significance of share repurchases in the Indian context. It is expected to provide an insight into the short-term effect of share repurchases (through average abnormal returns, if any), on stock price subsequent to the announcement; thereby investigating the existence of undervaluation and signaling hypothesis. Overall, it visualizes share repurchase as a value maximizing instrument (in the short-run) due to the element of financial flexibility. It demonstrates the validity of this proxy through findings, the supported literature and other published sources.

To fill the research gaps, the following null hypotheses have been formulated

H_{01}: Financial flexibility does not lead average abnormal returns on announcement of share repurchases.
H_{02}: Financial flexibility does not lead to cumulative average abnormal returns on announcement of share repurchases.

11.5 Research Methodology

11.5.1 Scope and Rationale of the Study

The present study covers a period of ten financial years (2003–2013). The BSE 500 index of the Bombay Stock Exchange has been chosen because it comprises of the top 500 companies based on their market capitalization. The index represents nearly 93% of the total market capitalization on BSE and includes 20 sectors of the economy. The present study focuses on India as it is one of the top five countries representing the emerging markets. As per the World Bank report, India is expected to have a growth rate of 7.5% in 2015–2016. In fact, according to the report, India

will lead major emerging economies in growth (http://www.sify.com Website 2015). Since share repurchase is a recent phenomenon in Indian stock market, the signaling mechanism/effect may be stronger with greater degree of information asymmetry.

Out of the 500 companies listed, 78 companies were financial companies and hence were excluded from the sample. Also the companies and announcements in respect of which data is not available have been excluded.

11.5.2 Sources of Secondary Data

The data of the repurchase announcements have been taken from Capitaline® database and SEBI website. The daily market prices have been downloaded from BSE website. Other published reports have also been used to interpret the findings and the results. The other secondary sources used to substantiate any missing data were the websites of Money Control, Economic Times and the individual company's websites.

11.5.3 Event Study Methodology

The event study methodology has been employed to compute abnormal returns and test statistics to examine the signaling impact of share repurchases announcements on returns of the sample companies (Brown and Warner 1985). This methodology has been employed in allied finance fields such as accounting, management, corporate finance, etc. It is also being widely used as a tool to study the impact of mergers and acquisitions, stock splits, new legislations, earning announcements, and other finance-related events, on the profitability of firms. A vast literature on the theory of event study methods also exists (Bowman 1983; Brown and Warner 1985). Following the seminal research chapters by Ball and Brown (1968) and Fama et al. (1969) event studies have become one of the widely used empirical techniques to detect abnormal changes in financial assets in the time period around various events.

Bowman (1983) identified the following five steps in conducting an event study:

(a) Identify the event of interest.
(b) Model the security price reaction.
(c) Estimate the excess returns.
(d) Organize and group the excess returns.
(e) Analyze the results.

11.5.4 Event Window

The event window examined is 31 days, i.e. 15 days prior to the announcement date (AD − 15) to 15 days after the announcement date (AD + 15) along with the announcement day itself (Wann et al. 2008). The announcement day (AD) is denoted as day zero (when share repurchase is announced for the first time in the public news chapters). The estimation period for the market model parameters (value weighted market index, BSE 500 index) is 150 days prior to the announcement day. Figure 11.1 depicts the event window and estimation window.

The following traditional market model has been used to estimate abnormal returns as per Eq. 11.1:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + E_{i,t} \tag{11.1}$$

The abnormal return (AR) of firm for each day has been computed as per the Eq. 11.2

$$AR_{i,t} = R_{i,t} - \left(\alpha_i + \beta_i R_{m,t}\right) \tag{11.2}$$

where α and β are the estimated parameters, $R_{i,t}$ is the expected return on stock i at time t, $R_{m,t}$ is the corresponding return on the BSE 500 index and $E_{i,t}$ is the error term. The average abnormal return (AAR) is obtained by aggregating the abnormal return for all the firms on each day of the event. To obtain the aggregative impact of the event during a particular time period, cumulative average abnormal returns (CAAR) are computed. The test statistic for AAR on day t during the event period and for CAAR for the event window (t_1, t_2) is given by Eqs. 11.3 and 11.4 respectively

$$t\text{-statistic} = \text{AAR}/\sigma(\text{AAR}_t) \tag{11.3}$$

$$t\text{-statistic} = \text{CAAR}\ t/(t_2 - t_1 + 1)1/2\sigma(\text{AAR}_t) \tag{11.4}$$

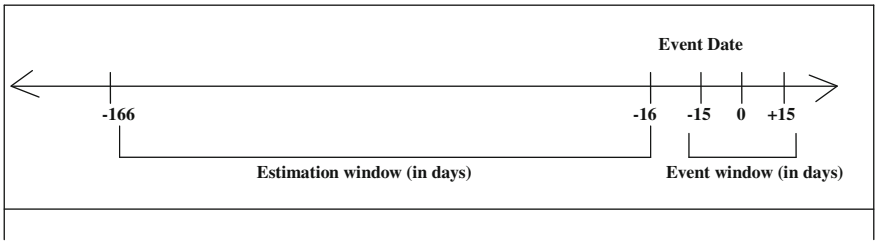

Fig. 11.1 Time period for event study (days). *Note* This figure displays the length of the event window and the estimation window for event study methodology

Table 11.3 Sample selection summary

	No. of companies	No. of announcements
Population	500	
Less		
Finance companies	78	
Companies left	422	
Companies announcing share repurchases	56	110
Companies/announcements not adhering to sample criteria	22	65
Total sample of number of companies	34	45

Note This table displays the final sample of number of companies and announcements for share repurchases

11.5.5 Clean Event Window Period

To ensure that the event window was not contaminated with any other type of announcement; only 'pure' share repurchase announcements will be considered. Hence, the announcements like stock/cash dividends and stock splits, bonus issue and share repurchase mergers, acquisitions, amalgamation, joint venture, capital investment, substantial orders from prestigious customers or any other such financial events during the event window will not considered as a part of the sample (McWilliams and Seigel 1997).

Table 11.3 displays the final sample size of companies and number of announcements considered for the present study after adhering to the sample criteria of clean event window.

11.6 Empirical Results

11.6.1 Price Reaction Results for 31-Day Event Window

Table 11.4 depicts that the announcement of share repurchases is beneficial to the shareholders. The shareholders are better off by earning a positive average abnormal return (AAR) of 0.27% on the announcement day (AD). The highest positive AAR of 1.72% is observed on AD − 3 day; this is the maximum and highly significant (at 1% level). On the other hand, the post-announcement window period observes the maximum AAR of 1.26% on AD + 13 day which is also statistically significant (at 5% level). Overall, the returns are positive for seventeen days in an event window of 31 days. Out of these positive returns, the three values are statistically significant at 1, 5 and 10% level of significance. Such a pattern of returns indicate that the share repurchase announcements are generally perceived to be positive by the market. Thus, it is evident from Table 11.4 that hypothesis (H_{01}),

Table 11.4 Average abnormal returns (AARs) and cumulative average abnormal return (CAARs) and their corresponding *t*-statistic values on and around share repurchase announcements for the years 2003–2004 to 2012–2013

Days	AAR (%)	*t*-statistic (AAR)	CAAR (%)	*t*-statistic (CAAR)	Kurtosis	Skewness	Standard deviation
−15	0.10	0.1804	0.10	0.0324	1.61	0.64	0.02
−14	−0.25	−0.4550	−0.15	−0.0493	−0.42	0.22	0.02
−13	−0.08	−0.1400	−0.23	−0.0745	−0.83	0.36	0.01
−12	−0.48	−0.8722	−0.70	−0.2311	−0.33	−0.52	0.02
−11	0.47	0.8541	−0.24	−0.0777	1.56	1.32	0.02
−10	−0.42	−0.7713	−0.66	−0.2162	3.07	−1.43	0.01
−9	0.40	0.7246	−0.26	−0.0861	0.52	0.16	0.01
−8	−0.23	−0.4144	−0.49	−0.1605	−0.04	0.43	0.01
−7	0.19	0.3520	−0.30	−0.0973	2.83	1.57	0.02
−6	−0.47	−0.8623	−0.77	−0.2522	−0.27	0.05	0.01
−5	0.97	1.7857***	0.21	0.0686	1.15	0.94	0.02
−4	0.64	1.1747	0.85	0.2795	−1.07	0.45	0.02
−3	1.72	3.1597*	2.57	0.8470	7.05	2.45	0.02
−2	0.24	0.4463	2.82	0.9272	3.69	−1.32	0.02
−1	−0.12	−0.2194	2.70	0.8878	−1.60	−0.08	0.02
0	0.27	0.4978	2.97	0.9772	−1.51	−0.09	0.02
1	−0.65	−1.1952	2.32	0.7625	−0.30	−0.97	0.01
2	−0.38	−0.6930	1.94	0.6381	−1.25	−0.34	0.01
3	0.24	0.4409	2.18	0.7172	−0.23	0.37	0.02
4	0.13	0.2343	2.31	0.7593	−0.45	0.18	0.01
5	−0.04	−0.0781	2.26	0.7453	1.12	0.43	0.01
6	−0.07	−0.1239	2.20	0.7230	−0.19	−1.05	0.01
7	0.46	0.8424	2.66	0.8744	4.13	1.59	0.02
8	−0.08	−0.1558	2.57	0.8464	2.78	−1.60	0.01
9	−0.21	−0.3934	2.36	0.7757	2.72	−1.29	0.02
10	0.45	0.8301	2.81	0.9248	−0.45	0.40	0.01
11	0.42	0.7659	3.23	1.0624	4.24	1.70	0.02
12	0.37	0.6834	3.60	1.1851	4.36	1.71	0.02
13	1.26	2.3109**	4.86	1.6002	5.93	2.13	0.03
14	0.43	0.7856	5.29	1.7413***	−1.19	−0.34	0.01
15	−0.44	−0.8095	4.85	1.5959	2.61	−0.73	0.02

Note (a) This table shows the average abnormal returns for 31 days around the announcement of share repurchases (day 0). The market model is used to compute the daily abnormal returns. (b) *Significant at 1%, **Significant at 5%, ***Significant at 10%

namely, that financial flexibility does not lead to average abnormal returns on announcement of share repurchases is rejected at 1 and 5% significance level. The negative returns are, however, not significant in any day of the event window.

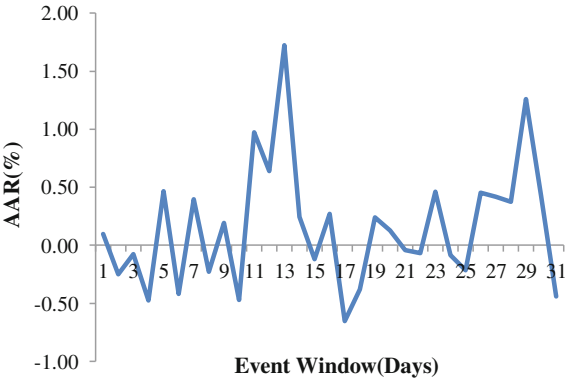

Fig. 11.2 AARs for share repurchase announcements. *Note* This figure depicts the AAR during the event window. Along the horizontal axis, event window (+15 days to −15 days) and the announcement date (day 0) is displayed. Along the vertical axis, average abnormal return has been exhibited

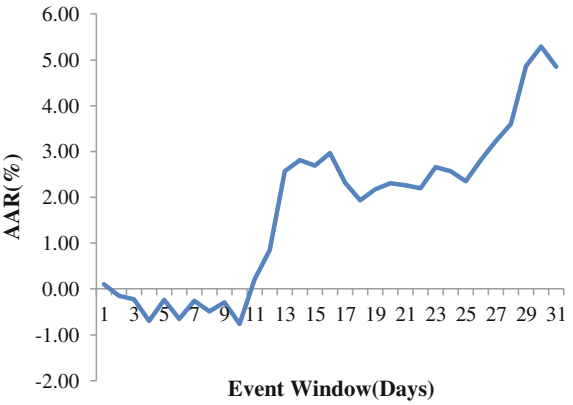

Fig. 11.3 CAARs for share repurchase announcements. *Note* This figure reports the CAAR during the event window. Along the horizontal axis, event window (+15 days to −15 days) and the announcement date (day 0) has been exhibited. Along the vertical axis, cumulative average abnormal return has been shown

The negative AARs for couple of days following the repurchase announcement can be explained by overreaction to such announcements and marginal correction thereafter. Such a pattern of negative abnormal returns just post-announcement might also be an indication that the share repurchases announcements does impact the valuation of shares in the long-run. It might be that the repurchase motive is to improve the shareholding of promoters of the company, and to provide short-term financial gains to the investors (Guthart 1967; Cudd et al. 1996; Mishra 2005). Hence, the results document the mixed nature of abnormal returns booking for the sample companies. Moreover, the figures of skewness, kurtosis and standard deviation can also be seen varying across the sample during the event window indicating high degree of volatility within the sample as evidenced by Babenko (2009). Figures 11.2 and 11.3 depict the trend of abnormal returns. Thus, the most beneficial window period for investor is to invest before the announcement date and to sell the share very next day of the announcement day. Further, it is also beneficial to the investors to sell shares in the pre-event period (due to positive AAR, on account of signaling effect) and sell them in post-event window period.

To examine the net magnitude of the overall returns, these returns have been cumulated over the event window. Table 11.4 presents the CAAR for each day during the 31-day event window and their corresponding *t*-statistic values. The CAAR of 2.97% has been reported on the announcement day. The highest cumulative average abnormal return (CAAR) has been reported of 5.29% and is statistically significant (at 10%) on AD + 14 day post the announcement and of 2.82% on AD − 2 prior to the announcement of share repurchases. Thus, null hypothesis (H_{02}), namely, that financial flexibility does not lead to cumulative average abnormal returns on announcement of share repurchases is rejected at 10% significance level. All CAAR values are positive post the event window period. In operational terms, it implies that the investors are likely to benefit during the post-announcement period at any given day of the window.

The results support the existence of undervaluation and signaling hypotheses in the Indian stock market (Bartov et al. 1998; Comment and Jarrell 1991; Gurgul and Majdosz 2005; Jagannathan and Stephens 2003; Sedzro 2009). The rationale for such results seems to be that the existing share prices are less than the stock's intrinsic value as supported by undervaluation hypothesis (Chowdhry and Nanda 1994; Baker et al. 2003). Perhaps, the sample companies perceive that the share repurchase will enable them to enhance the shareholders' value.

Various surveys also evince support to the signaling hypothesis. Wansley et al. (1989) found signaling as second important factor for firms repurchasing shares. Similarly, Tsetsekos et al. (1991) reported signaling the third most important motive. This suggests that decision to repurchase is in line with managers possessing superior information regarding the firm's economic value and hence support the undervaluation and signaling hypotheses (Baker et al. 2003; Block 2006).

The observed results also indicate that the effect of share repurchase announcement in market is short-lived, as can be observed from the Table 11.2 (for 1 day). Majority of positions in the securities are taken on the first day itself and then for the days following, its AARs are within range of ±1% for most of the days. This range bound returns are in line with the returns before the announcement date. The positive AAR during the pre-event days (from AD − 5 to AD − 2) is perhaps an indication of insider trading (Li and McNally 2007). It appears that there is no opportunity to book abnormal profits on a sustained basis as the prices adjust to the new information quickly. This aspect favours the semi-strong form of efficiency in the Indian stock market (Dua et al. 2010).

The above findings are consistent with earlier studies in other markets around the world where the firms experienced positive excess AARs following the announcements of share repurchases (Vermaelen 1981; Comment and Jarrell 1991; McNally 1999; Baker et al. 2003; Li and McNally 2007; Crawford and Wang 2012).

11.6.2 Price Reaction for Smaller Windows

For better understanding of abnormal returns, smaller event windows have been used. This exercise has been undertaken to determine the important periods for investment perspective. Table 11.5 contains the CAAR values and their corresponding t-statistics values for alternative smaller event windows. The announcement effect of share repurchases around smaller windows have been measured for (−1, 0), (0, +1), (−1, +1), (−5, +5), (+2, +5), (−2, −5), (+2, +10), (−2, −10), (−15, −2), (+15, +2) and (−15, +15) event windows. These event windows are used to control for information leakages and for 'after hours' announcements (Dasilas et al. 2008).

The CAAR is maximum (nearly 5%) and significant for window (−15, +15) making it the most important event window. The next best performing windows are (−2, −5) and (−2, −10) with CAARs of 3.58 and 3.05% and is statistically significant at 1 and 10%. The negative CAAR in windows (−1, +1) and (+2, +5) shows that there is a possibility of correction after the share repurchase announcement. The positive abnormal returns in the remaining smaller windows can be explained as marginal correction and profit booking takes place for around 2 days post announcement. The positive values of CAAR in these windows also signify that the effect of share repurchase announcements is significant for the investors, signaling the undervaluation of shares by the market. The incidence of *t*-values in this regard has further been inclined to the rejection of hypothesis (H_{02}) at 1 and 10% level of significance that financial flexibility does not lead to cumulative average abnormal returns on announcement of share repurchases.

Table 11.5 Cumulative average abnormal return (CAAR) for share repurchase announcements across various event windows for the years 2003–2004 to 2012–2013

Event window	CAAR (%)	*t*-statistic
(−15, +15)	4.85	1.5960
(−15, −2)	2.82	1.3798
(−2, −10)	3.05	1.8652*
(−2, −5)	3.58	3.2835**
(−5, +5)	3.03	1.6746
(−1, +1)	−0.50	−0.5294
(0, −1)	0.15	0.1968
(0, +1)	−0.38	0.0077
(+2, +5)	−0.05	−0.0479
(+2, +10)	0.49	0.3012
(+2, +15)	2.53	1.2402

Note (a) This table reports the cumulative average abnormal returns for 31 days around the announcement of cash dividend (day 0) across smaller windows. (b) *Significant at 10%, **Significant at 1 and 5%

11.6.3 Other Repurchase Motives of the Sample Companies

Besides undervaluation and signaling (as documented above), there seems to be some other motives as to why Indian firms might repurchase their own shares. The life cycle of the firm consists of stages wherein some firms are growing whilst the others are declining. Share repurchases facilitate in allocating funds from the declining firms to firms with more challenging opportunities. This has an added advantage as it enables the firms to lower the agency costs of free cash flows; otherwise it is apprehended that managers may invest these funds in non-productive activities/investments (Nohel and Tarhan 1998; Grullon 2000). Thus, reducing agency costs, better capital market allocations and wealth transfer appear to be other motivations for Indian firms.

Further, it appears that firms prefer to repurchase their shares (at the mature stage of their lifecycle) as an outlet to utilize free cash flows (Liang et al. 2011). Repurchase signals a decline in growth opportunities, resulting in reduction of risk (Peyer and Vermaelen 2009). This reduction in risk and free cash flows has been attributed as sources of positive abnormal returns by Grullon and Michaely (2004). These findings also lend some credence to leverage adjustment hypothesis as the firms repurchasing shares use less debt compared to non-repurchasing firms. Repurchases, thus, appear to be a tool for managing capital structure (Medury et al. 1992; Chan et al. 2004).

The results also suggest that the companies can reduce short-term fluctuations in prices by trading their own stock. This smoothens price discovery and provide credence to 'price support hypothesis' (Brav et al. 2005; Ginglinger and Hamon 2005; Cesari et al. 2011). The above findings are in tune with the surveys of Chief Finance Officers (CFOs) according to the published reports in Institutional Investor (July 1998, p. 30) and Institutional Investor (August 1997, p. 31). They opined that they would prefer share repurchase to utilize the excess cash and to add value for shareholder. These results also find support for Isagawa's (2000) model wherein firms with greater insider holdings and free cash flows but low growth opportunities are more akin to choose share repurchases.

11.7 Conclusion

Undoubtedly, share repurchase decisions effect the company's objective of maximizing the wealth of the shareholders. The empirical research presents evidence that the share repurchase announcements, by and large, have a positive impact in the market. The findings extend and support the results of the earlier studies. The main findings are listed below.

Share repurchase provides flexibility as a payout mechanism to distribute cash to shareholders. They have emerged as an effective capital management tool and are currently the dominant method of payout. This finding implies that share repurchase

is an important consideration in designing capital structure and this finding is similar to those of Graham and Harvey (2001), Brav et al. (2005), Denis and McKeon (2012).

The repurchases are moving at a snail's pace in India (Hyderabad 2013). They are still at their nascent stage compared to U.S. and other European countries.

Share repurchase announcements have positive information content resulting in positive average abnormal returns (Wang et al. 2009). The results documented support the existence of undervaluation and signaling hypotheses in the Indian stock market. These findings are in conformity with the earlier studies (Comment and Jarrell 1991; Bartov et al. 1998; Jagannathan and Stephens 2003; Gurgul and Majdosz 2005; Sedzro 2009). The empirical evidence also complements with the surveys of Wansley et al. (1989), Tsetsekos et al. (1991), Baker et al. (2003) and Block (2006) where signaling was mentioned as one most important reason for firms repurchasing shares.

Apart from strong support to signaling and undervaluation, it appears that Indian companies have some other motives behind repurchases. The results lend credence to motives like reducing agency costs, better capital market allocations through excess cash flows, wealth transfer, smoothening price discovery and adjustment of the capital structure. These results are in accordance with the findings of Nohel and Tarhan (1998), Grullon (2000), Brav et al. (2005), Ginglinger and Hamon (2005) and Cesari et al. (2011).

It is to be emphasized that the stock market reaction to the share repurchases announcements is similar to that of the western markets signaling the undervaluation of shares. Though, repurchases can be construed as a restructuring strategy, however, its impact is in short-run. Therefore, they are not to be considered as a substitution or replacement strategy.

The findings seem to have implications to the practicing corporate managers, policy makers (at government level), researchers and the academicians. The findings contribute to the existing literature on repurchase decisions of Indian firms. It also adds on to the existing literature as to why firms choose to payout their cash. The results are helpful in providing explanations for the share price around announcements of share repurchase. Since share repurchase has gained momentum in India; the regulations should be framed to prevent its misapplication. Finally, the results provide an insight as to how the Indian managers use the assumptions, models and decision rules generated and the practices which are in vogue as per existing literature on corporate financial decisions related to share repurchases.

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Chapter 12
Portfolio Selection in Indian Stock Market Using Relative Performance Indicator Approach

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12.1 Introduction

A collection of various financial assets held by an investor is called portfolio. The investors hold a number of assets to diversify portfolio and to reduce risk. Portfolio optimization is a decision-making process where two or more conflicting objectives such as maximizing return and minimizing risks are considered. It involves three phases, namely, asset selection, asset allocation, and asset management. Asset selection refers to the process of selecting a collection of assets from same or different asset classes. The asset class includes stocks, real estate, and bonds. The process of asset allocation helps the investors to decide how much money can be invested in which asset(s) to reduce the risk and maximize the return. The final step, asset management helps the investors to evaluate the portfolio and define strategies to buy, sell, or hold an asset(s).

The Mean-Variance (M-V) framework proposed by Markowitz (1952) to solve the portfolio optimization problem aims to find the "efficient frontier", which consists of a combination of various assets that minimizes the risk at various levels of return or minimizes return at various levels of risk. The concept of portfolio optimization has been extended by various researchers (Doerner et al. 2004; Chang et al. 2009; Chen et al. 2009; Cura 2009; Lin and Ko 2009; Soleimani et al. 2009; Golmakani and Fazel 2011).

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The standard M-V framework suffers from few limitations. Real-world data is not multivariate normally distributed as against assumed in M-V framework. The existing algorithms of quadratic program fail when constraints like bounding constraints and cardinality constraints are considered in the M-V framework (Maringer and Kellerer 2003; Singh et al. 2010).

With remarkable increase in number of listings of companies on a stock exchange and accessibility and availability of various sources of information like financial statements, stocks prices, and economic conditions, it is challenging for the investors to screen and select the most profitable stocks. Evaluation and selection of appropriate assets are considered to be important processes since they influence asset allocation process. The scope of this chapter is limited to asset selection phase of portfolio optimization. The asset type considered is limited to stocks. The main focus of this chapter is to evaluate the financial performance of the firms using Relative Financial Performance Indicator (RFPI) and, thus, aid the investors to screen and select stocks for investment.

Since its foundation by Charnes et al. (1978), DEA is a well-known technique to measure efficiency of comparable units. But it fails to differentiate efficient firms from inefficient firms when the number of input and output parameters is larger than the number of comparable units. This problem is known as *curse of dimensionality*. To overcome this, a hybrid Principal Component Analysis (PCA)—Data Envelopment Analysis (DEA) is used. The study does not indicate that this is the only method of decision-making, but shows the application of PCA-DEA as a strategy for selection of stocks.

A brief review of the literature is provided in the next section. Section 12.3 discusses PCA-DEA approach followed by methodology adopted for the study in Sect. 12.4. Section 12.5 presents results and discussion followed by the study's conclusion in Sect. 12.6.

12.2 Previous Works

During the past decade, many researchers have used DEA as a strategy for stock selection in various stock exchanges. Ismail et al. (2012) used DEA to construct portfolio(s) of stocks from the property sector in Malaysian stock market for the period 2004–2005. Dividend yield, trading volume, liquidity, book-to-market, size, price-earnings, risk, leverage ratios, and asset utilization ratios were considered as input parameters. The output variables were return-on-equity and return-on-asset. The performance of the portfolio was measured using Cumulative Annual Returns (CAR). The study concluded that the portfolio comprising of DEA-efficient firms produced positive CAR over a long period.

Edirisinghe and Zhang (2008) proposed a relative financial strength indicator (RFSI) using DEA for firms from US technology sector. RFSI was calculated in two ways: first using the raw numbers (total assets, inventory, accounts receivable, revenue, long-term debts, net income, and total liabilities) from the financial

statements and second, using financial ratios (profitability, liquidity, leverage, valuation, asset utilization, and growth ratios). Further, the portfolio constructed using RFSI of financial ratios performed better.

Chen (2008) compared two strategies for selection of stocks listed on Taiwan Stock Exchange. In the first strategy, market equity was considered as the size of the firm. The portfolio was formed by including firms of smaller size. In the second strategy, DEA was used to select the firms. The portfolio constructed using DEA produced superior returns.

The effectiveness of DEA as a stock selection strategy was tested for Finnish non-financial stocks over the period of 1993–2008 (Pätäri et al. 2010). Three variants of DEA, namely, CCR (refers to the names of researchers Charnes, Cooper and Rhodes), BCC (refers to the names of researchers Bank Charnes and Cooper) and super-efficiency models were used. The portfolios obtained using DEA performed better than the market portfolio (Pätäri et al. 2010). Pätäri et al. (2012) carried out a similar study by combining both momentum and value indicators into a single efficiency score. Based on the efficiency scores, the stocks were classified into three-quantile portfolios. The top quantile portfolio performed better than the market portfolio.

The effectiveness of standard DEA and weight-restricted DEA model was compared as a stock selection strategy in China A-share stock market (Ke et al. 2008). Weight-restricted DEA increases the discriminatory power of DEA. Weight-restricted DEA model was found to be effective for constructing risky portfolios. The relative importance of input and output parameters is provided by experts.

In another study by Singh et al. (2010), the portfolios obtained using DEA and ordered-weighted averaging (OWA) operator were compared for Nifty stocks during the period 2005–2007. The portfolio formed using DEA showed better returns while the portfolio formed using OWA operator performed better.

Hsu (2014) proposed a four-stage integrated approach for portfolio optimization for stocks in the semiconductor section of Taiwan Stock Exchange. In the first stage, DEA was used to select potential stocks based on historical financial performances. In the second stage, portfolio was constructed using extended M-V framework. In the third stage, Genetic programming was used to build a forecasting model to predict stock price. In the last stage, transaction rules were defined for buying, selling, or holding the stocks.

Review of previous studies highlights the effectiveness of DEA as a stock selection strategy for portfolio optimization in various stock markets. Curse of dimensionality of DEA leads to misclassification of inefficient firms as efficient. Weight-restricted DEA was used to overcome this limitation. But the expert opinion to analyze the relative importance of output and input parameters may be biased and subjective. Hence, misclassification of firms costs a lot to the investors. None of the above-mentioned works addressed the issue of reducing the output and input variables to increase the discriminatory power of DEA without the need for expert's judgment and its implementation for selection of stocks.

12.3 Principal Component Analysis—Data Envelopment Analysis (PCA-DEA)

This section briefly discusses Data Envelopment Analysis (DEA) and its limitations. It also gives an overview about Principal Component Analysis (PCA) and the formulation of PCA-DEA model.

12.3.1 Data Envelopment Analysis

In their seminal work, Charnes et al. (1978) and Banker et al. (1984) laid the foundation of Data Envelopment Analysis (DEA) by extending the work of Farrell (1957). DEA is a non-parametric linear programming technique that helps to determine the relative efficiencies of comparable units, which are known as decision-making units (DMUs). Relative efficiency is calculated as the ratio of the weighted average of output parameters to the weighted average of input parameters. A DMU is considered to be efficient if it has an efficiency score of 1. Otherwise, it is considered to be inefficient.

The linear programming formulation of CCR model for n comparable units is represented in Eq. (12.1). Readers are suggested to refer Adler and Yazhemsky (2010) to read more about different DEA models and their properties.

$$\begin{aligned} &\max_{Q,P} PY^a \\ &\text{s.t.} \quad QX^a = 1 \\ &QX - PY \geq 0 \\ &P, Q \geq 0, \end{aligned} \tag{12.1}$$

where

Y denotes vector of outputs;
X denotes vector of inputs;
X^a represents the input column of DMU under consideration, DMU_a;
Y^a represents the output column of DMU under consideration, DMU_a;
P represents the vector of output weights;
Q represents the vector of input weights.

Wide applicability and use of DEA is due to its ability to handle multiple input and output parameters for evaluating the relative efficiency. But the accuracy of evaluation of efficiency is affected by the proportion of number of DMUs and number of output and input parameters (Golany and Roll 1989; Dyson et al. 2001).

The conventional and easiest way to resolve this issue is to eliminate few parameters but it affects the efficiency scores (Adler and Yazhemsky 2010). Another alternative is use of weight-restricted DEA but it suffers from subjectiveness of experts' opinion (Ke et al. 2008).

Research conducted to reduce the number of input and output variables for DEA include integrating principal component analysis with DEA (PCA-DEA) (Ueda and Hoshiai 1997; Adler and Golany 2001), variable reduction using partial correlation (Jenkins and Anderson 2003), regression-based analysis (Ruggiero 2005) and efficiency contribution measure (ECM) (Pastor et al. 2002). A comparative review of these methodologies can be found in Adler and Yazhemsky (2010) and Nataraja and Johnson (2011). The performance of ECM is moderate, but the run-time is long. Regression-based analysis requires shorter run-time, but the performance is not as good as ECM. Variable reduction using partial correlation is same as that of removal of one or more input and/or output parameters, whereby the efficiency of the comparable units is affected. The performance of PCA-DEA was found to be better since the information loss is minimum. The information in the original variables is retained in the form of principal components. The run-time of PCA-DEA is smallest because of its non-iterative nature.

12.3.2 Principal Component Analysis

Principal Component Analysis (PCA) is a statistical technique that transforms a dataset into a set of linearly uncorrelated variables called principal components (PC) (Hair et al. 2009). Let the random vector of output (or input parameters) to be transformed be $Y = [Y_1, Y_2, \ldots, Y_p]$. The correlation matrix of vector Y is represented as C with normalized eigenvectors $l_1, l_2, \ldots, l_p$ and eigenvalues $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_p \geq 0$.

The linear combinations are represented as

$$Y_{\mathrm{PC}_i} = l_i^t Y = l_{1i}^t Y_1 + l_{2i}^t Y_2 + \cdots + l_{pi}^t Y_p \tag{12.2}$$

$$\mathrm{Var}(Y_{\mathrm{PC}_i}) = l_i^t C l_i, \quad i = 1, 2, \ldots, p \tag{12.3}$$

$$\mathrm{Correlation}(Y_{\mathrm{PC}_i}, Y_{\mathrm{PC}_k}) = l_i^t C l_k, \quad k = 1, 2, \ldots, p, \quad i = 1, 2, \ldots, p, \quad i \neq k, \tag{12.4}$$

where t represents the transpose operator.

The variance of the dataset is explained by PCs in a certain ratio, where ratio represents the eigenvalues of the correlation matrix C. Descending order of the eigenvalues indicates that the PC_1 explains the maximum variance of the dataset compared PC_2 and so on. This indicates the PC_1 is correlated with at least few of the original output (or input parameter, as the case may be). The number of PCs formed is equal to or less than the number of variables in the dataset. The orthogonality of the eigenvectors accounts for the uncorrelated principal

components. In other words, PC_1 is not correlated to PC_2, which is not correlated to its lower level PCs. All the components extracted have two important properties: each component explains the maximum variance in the dataset that was not explained by its predecessor, and the components are uncorrelated with its respective preceding component.

12.3.3 PCA-DEA Formulation

The concept of integrating Principal Component Analysis (PCA) with Data Envelopment Analysis (DEA) was developed by Ueda and Hoshiai (1997) and Adler and Golany (2001, 2002). The PCA-DEA model overcomes the limitation of DEA model, which fails to discriminate the efficient DMUs from the inefficient DMUs when the number of input and output parameters is large in comparison to the number of DMUs.

The DEA model (Eq. 12.1) is transformed to accommodate the principal components, instead of the original data. As seen in Eq. (12.3), principal components are nothing but the linear combination of weighted input and output parameters. The formulation of CCR model is transformed in such a way that when all the PCs are included in the PCA-DEA model, the resulting efficiency would be same as that of standard DEA. The PCA-DEA formulation for CCR for n comparable units is shown below (Adler and Yazhemsky 2010):

$$\begin{aligned} &\max_{Q_{\mathrm{PC}} P_{\mathrm{PC}}} P^t_{\mathrm{PC}} Y^a_{\mathrm{PC}} \\ &\text{s.t.} Q^t_{\mathrm{PC}} X^a_{\mathrm{PC}} = 1 \\ &Q^t_{\mathrm{PC}} X_{\mathrm{PC}} - P^t_{\mathrm{PC}} Y_{\mathrm{PC}} \geq 0 \\ &Q^t_{\mathrm{PC}} L_x \geq 0 \\ &P^t_{\mathrm{PC}} L_y \geq 0 \\ &Q_{\mathrm{PC}} \text{ and } P_{\mathrm{PC}} \text{ are free} \end{aligned} \tag{12.5}$$

where, Q_{PC} and P_{PC} are the vectors of output and input weights, respectively. From the definition of principal components, we know that $Y_{\mathrm{PC}} = L_y Y$ and $X_{\mathrm{PC}} = L_x X$, where L_y and L_x are the PCA coefficients of output and input data, respectively. So, $Q_{\mathrm{PC}} \equiv Q_{\mathrm{PC}} L_x X$, which implies that $Q = Q_{\mathrm{PC}} L_x$ and $Q_{\mathrm{PC}} \equiv P_{\mathrm{PC}} L_y Y$ implying $P = P_{\mathrm{PC}} L_y$ (Adler and Golany 2002). This model is equivalent to that of the standard DEA model where *PCs* explain 100% variance of the dataset.

In PCA, PCs are prioritized in descending order of importance. Constraints $Q_{PCi} - Q_{\mathrm{PC}i+1} \geq 0$ and $P_{\mathrm{PC}i} - P_{\mathrm{PC}i+1} \geq 0$ ensure that the weight of PC_1 is at least equal to or greater than PC_2, the weight of PC_2 to be at least equal to or greater than PC_3 and so on. In this way, PCA increases the discriminating ability of the DEA model (Adler and Golany 2002).

The PCA-DEA model is robust to sample size (Yap et al. 2013). In PCA-DEA model, the PCs that do not contribute much to the variance of the data are dropped. The complete information on an input or output parameter is not lost until the principal component weight representing the variable is eliminated. In this way, the information loss is minimized. In addition, PCA-DEA is similar to weight-restricted DEA without the need for expert opinion, which is subjective.

12.4 Methodology

12.4.1 Data Description

The data sample consists of non-financial stocks quoted on National Stock Exchange (NSE) which was 1523 as of July 2014 (NSE 2015). On the basis of similar business functionality, the stocks were classified into 15 sectors. Investing in stocks from different sectors helps to diversify the risk. The period of study is 2006–2013.

Delisted, inactive, and suspended stocks during the period of study were not considered. Stocks with incomplete data were also eliminated. At the end of this process, the number of stocks was reduced to 523 as shown in Table 12.1. Both the financial statement data and the stock price data were collected from ACE Equity database.

Table 12.1 Sectors and number of firms

S. No.	Sector	Number of firms
1	Food and beverages	33
2	Personal products	13
3	Textile	49
4	Industrial metals	31
5	Chemicals	76
6	Construction	27
7	Pharmaceutical	41
8	Media	21
9	ICT	47
10	Automobile	52
11	Construction material	31
12	Consumer services	35
13	Power	10
14	Engineering	35
15	Electric equipment	22
	Total	523

12.4.2 Input and Output Parameters

Appropriate input and output parameters should be selected for evaluating the RFPI of the firms (Golany and Roll 1989). Raw financial numbers such as total assets and total liabilities do not aid in differentiating the healthy stocks from the unhealthy stocks. Hence, the financial ratios are chosen to establish the financial performance of the firms Edirisinghe and Zhang (2007). The financial ratios of financial firms are different from that of non-financial firms, hence, the latter group is not considered for the analysis.

The financial health of a firm can be analyzed using six aspects: liquidity, leverage, asset utilization ratio, profitability, growth ratio, and valuation ratio. The generation of revenue by a firm is explained using profitability and growth ratios, hence, they are classified as output parameters. Valuation ratio explains the perception of the investors towards the success of the firm. The planning and operational strategies of the firm are evaluated using asset utilization, liquidity, and leverage ratios; hence, they constitute the input parameters for PCA-DEA analysis (Edirisinghe and Zhang 2008). A set of 18 financial ratios is used as input and output parameters as shown in Table 12.2. These parameters are supported by the work of Powers and McMullen (2000), Feroz et al. (2003), Edirisinghe and Zhang (2008), Hwang et al. (2010), Ismail et al. (2012), and Tehrani et al. (2012).

Table 12.2 Input and output parameters

Parameter	Measures	Financial ratio
Input	Liquidity ratios	Debt to equity ratio
		Quick ratio
		Current ratio
	Leverage ratios	Solvency ratio I
		Solvency ratio II
		Leverage ratio
	Asset utilization	Asset turnover
		Inventory turnover
		Receivables turnover
Output	Profitability ratio	Return-on-assets
		Earnings per share
		Net profit margin
		Return-on-equity
	Growth ratio	Revenue growth rate
		Earnings per share growth rate
		Net income growth rate
	Valuation ratio	Price to earnings ratio
		Price to book ratio

12.4.3 PCA-DEA Framework for Stock Selection

The efficiency calculated using PCA-DEA is known as Relative Financial Performance Indicator (RFPI). Here, DMUs consist of firms from different sectors. As seen from Table 12.2, the number of DMUs in few sectors, namely, power sector and construction sector do not satisfy the rule of thumb proposed by Golany and Roll (1989) and Dyson et al. (2001). This affects the discriminatory power of the standard DEA model, thus, classifying the majority of DMUs as efficient. Integrated PCA-DEA approach overcomes this problem of DEA (Adler and Yazhemsky 2010). Further, PCA-DEA model is robust to the size of DMUs (Yap et al. 2013). Hence, PCA-DEA is approach is used for the analysis.

During the data preprocessing phase, the data is normalized by dividing the elements of each input and output data by its respective mean to overcome the scaling issues and the round-off errors problems faced by few mathematical programming softwares (Sarkis 2007).

The financial performance of the firms from various sectors during the period of study is evaluated using the integrated PCA-DEA approach. The PCA-DEA approach for stock selection is shown in Fig. 12.1. The steps of the approach are enumerated below

1. Run Principal Component Analysis (PCA) for inputs and outputs separately.
2. The information level in the model is decreased by 5% at each stage starting from 100% till it reaches 80%. Information level refers to the amount of information that should be retained in the model. In other words, it represents the amount of variance in the input and output that is explained by their respective principal components (X_{PC} and Y_{PC}). When the information level is reduced below 80%, the model classifies the efficient firms as inefficient. To avoid this overestimation bias, the efficiency is calculated till 80% information level. As mentioned in the previous section, when PCs explain 100% variance of dataset, the PCA-DEA model is nothing but the standard DEA model.
3. Using Eq. (12.5), calculate the relative efficiency of the firms at each information level.
4. Repeat steps 2 and 3 for all sectors and years.
5. Examine the efficiency of the firms at various information levels (i.e., 100, 95, 90, 85, and 80%). Identify the desired information level that meets the investor's desired level of discrimination.
6. The firms with the RFPI score of 1 are considered to be investment worthy. The criterion for selecting stocks is that for a desired information level, the stocks should have a RFPI score of 1 throughout the period of study.

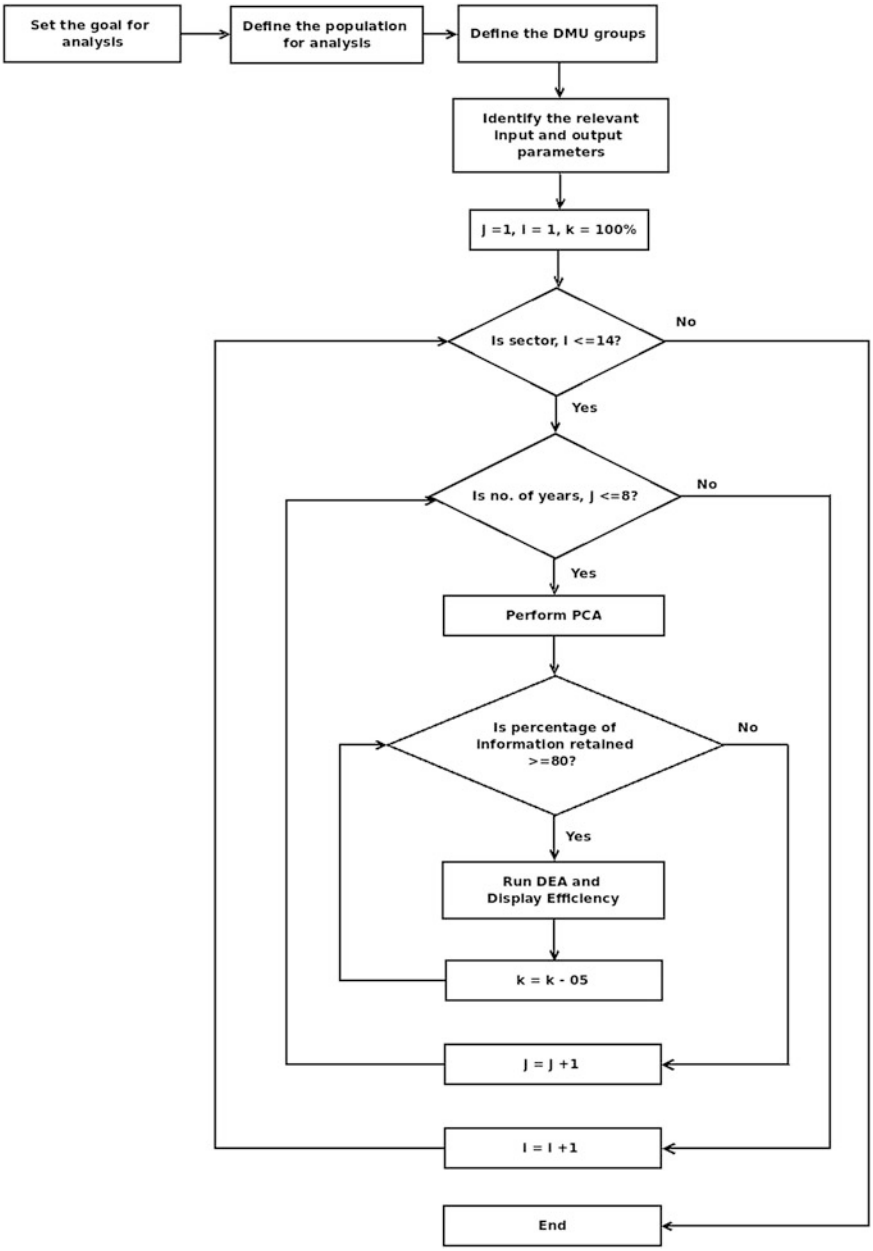

Fig. 12.1 Proposed approach for stock selection using PCA-DEA

12.5 Results and Discussion

12.5.1 Principal Component Analysis

PCA helped to increase the discriminatory power of DEA by reducing the dimensions of the linear program. The PCA results of firms from Food and Beverages sector for the year 2007 are shown in Table 12.3. From the table, it can be seen that the first principal component of input parameter PC_{x1} captures at least 62% of the variance in the data. When PC_{x2} is considered (in addition to PC_{x1}), almost 93% of the total variance is explained. In case of output, PC_{y1} explains at least 85% of the total variance in the data. In Table 12.3, rows 3–11 and 14–22 represent the PCA linear coefficients of inputs and outputs, respectively.

When the information level is 95% (i.e., 95% of the variance is explained by PCs). PC_{x3} to PC_{y9} of the input parameters can be dropped for efficiency calculation. It can be seen from Table 12.3, none of PCs dropped solely influences an entire input variable L_{x1}, …, L_{x9}, with no contribution of other PC combinations. Though dropping of few PCs causes little loss of information but it is not same as dropping of an entire input/output parameter.

Table 12.3 Principal component analysis for firms under food and beverages sector for the year 2007

Inputs (L_x)	PC_{x1}	PC_{x2}	PC_{x3}	PC_{x4}	PC_{x5}	PC_{x6}	PC_{x7}	PC_{x8}	PC_{x9}
% Correlation explained	62.156	31.159	5.776	0.412	0.340	0.107	0.036	0.014	0.001
L_{x1}	0.006	0.004	0.012	−0.008	1.009	−0.032	−0.083	0.043	−0.004
L_{x2}	−0.195	−0.106	0.045	1.235	−0.008	0.020	−0.321	0.173	−0.236
L_{x3}	0.645	−0.050	−0.002	−0.147	0.004	−0.003	−0.091	−0.171	−2.060
L_{x4}	0.607	−0.052	−0.011	−0.152	0.004	−0.003	−0.078	−0.165	2.126
L_{x5}	−0.112	−0.032	0.057	−0.292	−0.062	0.032	1.281	−0.229	0.190
L_{x6}	−0.005	−0.062	0.024	0.024	−0.032	1.009	0.042	−0.020	−0.007
L_{x7}	−0.201	−0.264	−0.067	0.158	0.031	−0.016	−0.234	1.306	−0.035
L_{x8}	−0.010	0.027	1.017	0.055	0.012	0.024	0.074	−0.091	−0.106
L_{x9}	−0.078	1.163	0.022	−0.107	0.004	−0.053	−0.034	−0.305	−0.053
Outputs (L_y)	PC_{y1}	PC_{y2}	PC_{y3}	PC_{y4}	PC_{y5}	PC_{y6}	PC_{y7}	PC_{y8}	PC_{y9}
% Correlation explained	85.841	13.359	0.309	0.230	0.156	0.068	0.030	0.004	0.003
L_{y1}	0.010	0.025	1.048	0.016	−0.024	−0.004	−0.203	−0.073	−0.039
L_{y2}	0.004	0.001	−0.004	0.011	−0.048	1.007	0.049	0.033	−0.011
L_{y3}	−0.068	−0.030	0.015	1.053	0.030	0.010	−0.065	−0.162	0.005
L_{y4}	0.514	0.019	0.009	−0.056	−0.027	0.003	−0.069	−0.017	9.713
L_{y5}	0.515	0.018	0.010	−0.056	−0.028	0.003	−0.067	−0.018	−9.706
L_{y6}	0.019	1.150	0.022	−0.028	−0.042	0.001	−0.132	−0.387	0.056
L_{y7}	−0.035	−0.046	−0.024	0.030	1.047	−0.045	−0.204	0.031	0.062
L_{y8}	−0.023	−0.239	−0.057	−0.103	0.003	0.023	−0.495	1.583	0.047
L_{y9}	−0.060	−0.106	−0.139	−0.050	−0.137	0.033	1.482	−0.628	−0.111

12.5.2 RFPI of the Firms

The firms that have an RFPI score of 1 are considered to be financially healthy and investment worthy. Descriptive statistics of the RFPI measure of the firms from Personal Products sector during year 2013 for various information levels is shown in Table 12.4. First row represents the percentage of information retained in the model (i.e., the amount of variance explained by $PC_x s$ and $PC_y s$). As mentioned earlier, when $PC_x s$ and $PC_y s$ explain 100% variance in the dataset, it is same as the standard DEA model. Hence, column 2 represents the descriptive statistics of the standard DEA model. Columns 3–6 represent the descriptive statistics of PCA-DEA model for 95–80% information level. Around 92% of firms are found to be DEA efficient while only 42% of the firms are found to be efficient in PCA-DEA model at 95% information level. It can be observed that the standard DEA model overestimated the inefficient firms.

The RFPI scores of the firms from the Construction Material sector throughout the 8 years (i.e., 2006–2013) are shown in Table 12.5. The first column represents the firms, i.e., DMUs for PCA-DEA model. Columns 2–9 represent the efficiency of the firms for years 2006–2013 when the information level is 100% (i.e., standard DEA model). Columns 10–17 represent the efficiencies of firms when 95% variance of dataset is explained. The RFPI scores corresponding to 90, 85, and 80% of information level are not shown here.

The firms that are with RFPI score of 1 throughout 8 years (i.e., from 2006 to 2013) are considered to be the potential candidates for next stage of portfolio optimization, i.e., asset allocation. For instance, The CM_6 is found to have a RFPI of 1 throughout all 8 years, hence, can be shortlisted for investment. Whereas, the RFPI score of CM_19 is 1 in all years except 2006, is not considered for investment. The same criterion is applied to firms in remaining 14 sectors. The number of potential candidates in different sectors is shown in Table 12.6. The stocks from different sectors are considered in order to diversify the unsystematic risk in a portfolio, thus reducing the total risk of the portfolio. A total of 115 potential stocks are obtained using standard DEA while 41 potential stocks are obtained using PCA-DEA. This reiterates the fact that the DEA model overestimates the efficient firms.

Table 12.4 Descriptive statistics of efficiency of firms (personal products sector, year 2013) for various information levels

	Information level in the model				
	100%	95%	90%	85%	80%
Minimum efficiency	0.6257	0.1672	0.1198	0.1198	0.1198
Maximum efficiency	1	1	1	1	1
Average RPFI	0.9712	0.7180	0.6760	0.6760	0.6760
Investment worthy firms (%)	92.30	46.15	15.38	15.38	15.38
Total number of firms	13	13	13	13	13

Table 12.5 PCA-DEA results for construction material sector

% Information retained	100%								95%							
DMUs	2013	2012	2011	2010	2009	2008	2007	2006	2013	2012	2011	2010	2009	2008	2007	2006
CM_1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
CM_2	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	1	1	1	1	1	0.8192	1	1
CM_3	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	0.9749	0.6907	0.9441	1	0.9823	1	1	0.9884
CM_4	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	1	1	1	1	1	1	1	0.9741
CM_5	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	0.9554	1	1	1	1	1	1	1
CM_6	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	1	1	0.9225	0.9884	1	1	1	1
CM_7	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	1	1	1	1	1	0.6336	1	1
CM_8	0.8511	1	1	1	1	1	1	0.9585	0.6619	1	0.8089	0.8895	0.7251	1	1	0.8656
CM_9	1	1	1	0.6429	0.9307	1	1	1	1	1	1	0.5720	0.7349	1	1	1
CM_10	1	1	1	1	1	0.7808	1	1	0.9338	1	0.7866	0.7111	1	0.3903	0.6573	1
CM_11	1	1	0.8303	0.8810	1	1	1	1	1	1	0.7100	0.6784	0.9716	0.9119	0.8020	0.8475
CM_12	1	1	1	1	1	0.6784	0.6881	1	1	1	1	1	1	0.4946	0.4550	1
CM_13	1	1	1	0.6441	0.8131	0.5468	0.9415	1	1	0.9594	1	0.5742	0.5828	0.3829	0.7729	0.9226
CM_14	1	1	1	0.9599	0.8358	1	1	1	0.9726	1	0.7729	0.6749	0.6441	0.5988	0.9530	1
CM_15	1	1	1	1	1	1	1	0.8991	1	0.7909	0.8630	0.6332	1	0.7040	1	0.565917
CM_16	0.8104	0.7591	0.4438	0.9983	0.5383	1	1	1	0.8055	0.6595	0.4083	0.8762	0.5050	0.9822	0.9929	1
CM_17	1	1	1	0.7915	0.8385	0.9337	1	0.7136	1	1	0.9993	0.5789	0.7259	0.6893	0.8259	0.5769
CM_18	1	1	1	1	1	1	1	0.7754	1	1	0.7954	0.5470	1	0.7912	0.8621	0.6955
CM_19	1	1	1	1	1	1	1	0.9156	0.8837	1	1	1	1	1	1	0.7702
CM_20	1	1	0.5855	0.8821	0.9522	1	0.9372	1	1	1	0.3433	0.5642	0.6396	0.5116	0.7126	0.8795
CM_21	1	0.7841	1	0.1804	1	1	1	1	1	0.3874	1	0.0278	1	0.7122	0.9279	0.9075
CM_22	0.2548	0.9779	1	0.1618	0.4518	1	1	1	0.2232	0.5689	1	0.0960	0.3685	1	1	1
CM_23	0.54	0.45	1	1	0.6173	0.7656	0.6781	0.8360	0.25	0.54	0.45	1	0.4125	0.4252	0.5218	0.7406

(continued)

Table 12.5 (continued)

% Information retained	100%								95%							
CM_24	1	0.3540	0.8465	0.8807	1	1	0.7138	0.7475	1	0.3053	0.6797	0.7218	1	0.7610	0.6548	0.5567
CM_25	0.1147	1	0.9084	0.7400	1	1	1	1	0.0873	1	0.6572	0.6793	1	1	1	1
CM_26	1	1	1	0.8598	0.7049	0.5342	0.7847	0.6513	0.9881	0.8085	0.7921	0.7960	0.6597	0.3615	0.5998	0.5955
CM_27	1	1	0.4024	0.1657	0.4694	1	0.0883	1	1	1	0.2636	0.1012	0.1315	1	0.0313	1
CM_28	0.3290	1	0.5404	1	0.5956	0.8613	1	0.5487	0.2536	1	0.4202	1	0.5642	0.5673	1	0.5275
CM_29	0.9362	1	1	1	1	1	1	1	0.7812	1	1	0.7625	1	1	1	1
CM_30	1	1	1	1	0.9938	1	1	1	1	1	1	1	0.9428	1	0.9989	1
CM_31	1	0.6998	0.8972	0.7986	1	0.3627	0.6695	0.8186	1	0.6048	0.7409	0.6719	1	0.1949	0.5908	0.5474
Efficient firms (%)	**77.42**	**74.19**	**70.97**	**51.61**	**58.06**	**67.74**	**70.97**	**64.52**	**58.06**	**51.61**	**38.71**	**35.48**	**48.39**	**38.71**	**38.71**	**45.16**

Table 12.6 Number of efficient firms in different sectors

S. No.	Sector	% Information retained	
		100%	95%
1	Food and beverages	10	3
2	Personal products	8	1
3	Textile	6	3
4	Industrial metals	7	3
5	Chemicals	7	5
6	Construction	11	3
7	Pharmaceutical	8	4
8	Media	2	1
9	ICT	7	2
10	Automobile	8	3
11	Construction material	7	1
12	Consumer services	11	4
13	Power	8	1
14	Engineering	9	4
15	Electric equipment	6	3
	Total	**115**	**41**

12.6 Conclusion

The focus of chapter was to screen and select the stocks quoted on NSE based on their historical financial performances. The financial performances were assessed in the form of RFPI using standard DEA and PCA-DEA with varying information levels. Standard DEA model helped in evaluating the financial health of firms and in selecting the stocks but it misclassified several inefficient firms to be efficient. Since portfolio optimization is a decision-making process where the investors select the stocks with high return and low risk, investing in an inefficient firm could be costly. PCA-DEA model was used to overcome this limitation, where PCA helped to reduce the number of input and output parameters with minimum loss of information. It is advantageous than weight-restricted DEA which employs experts' opinion to obtain the relative importance of input and output parameters.

In addition, the results obtained from the model can be used by the firms to benchmark their performance with those that are best within their industry. The inefficient firms can try to adopt the process(es) of the efficient firms to improve their performance.

The study can be extended to next phase of portfolio optimization, i.e., asset allocation, where the stocks selected in this can be used as the input. The applicability of the model can be tested for stock selection in other stock exchanges.

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Chapter 13
A Flexible Approach to Mitigation of Supply Risk Through Scenario Modelling

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13.1 Introduction

Risk in an organization can generally be described as any exposure that creates a potential threat to the life of the business. Supply chain disruptions might result in financial losses, a negative corporate image or a bad reputation eventually accompanied by a loss in demand as well as damages in security and health (Jüttner et al. 2003).

In the globalized world of intensive competition, supplying right material at right time of right quality at right price is very important for the survival of a firm. In order to ensure uninterrupted supply, it is necessary that suppliers supply quality materials as per the given delivery schedule. Delays in receipt of the material, or mismatch in quantity supplied, or material being of inferior quality or damaged, or the alteration in commercial terms delaying the supply from suppliers, are common problems in Indian manufacturing sector which impact the shop floor operations and production schedules and thus the credibility and business potential of the Indian industry.

Gaonkar and Viswanadham (2004) suggested that along with strategic and tactical level, supply chain needs to be robust at operational level. According to the authors, at the operational level, companies require systems to work on various deviations and disruptions from various partners so that the business processes are synchronized and deliveries are undertaken within customer delivery windows and

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cost limitations. The tools of supply risk management can be of two types: preventive and reactive. Preventive tools tackle the cause of the risk by finding a solution to eliminate the risk and its factors, Mangla et al. (2014), for example: by certifying suppliers, and building relationship with suppliers, supplier development, improving information transparency, etc. Reactive tools are effect-oriented measurements that do not directly act on the risks but strive for absorbing the damage caused by a risk and cushioning the consequences of risks by say building inventory, multiple sourcing, penalizing suppliers, adjusting order quantities, changing mode of transportation, etc. As claimed by Thun and Hoenig (2011), reactive supply chain management is effective in terms of external impacts on the one hand, but leads to inefficiencies due to the redundancies on the other hand. Contrary to that, preventive supply chain risk management supports the creation of a resilient supply chain.

Gaonkar and Viswanadham (2004), state that compared to 'just in case' way of maintaining inventories all along the chain, employing dual or multi-sourcing and manufacturing at multiple sites is a highly inefficient option. A better option would be to first design a sourcing strategy taking into account the disruption costs for the most relevant failure modes and then putting in place contingency plans for each disruption that include both, description of the procedures to follow and a definition of roles and responsibilities. In this chapter, an attempt is made to suggest 'scenario modelling' as a flexible proactive measure to mitigate the operational supply risks.

13.2 Literature Review

Although many companies are aware of risks that might influence their supply chain, managers fail to implement suitable instruments of supply chain risk management (Tang 2006). A possible reason for disregarding these instruments is that some risks are eventually underestimated in terms of their likelihood or impact on the supply chain. Another reason might be that managers are simply not familiar with appropriate instruments and neglect them accordingly. Finally, the difficulty to quantify the benefits of hedging against supply chain risks might hinder the implementation of appropriate instruments. However, certain events in the recent past have stressed the need to consider supply risk (Zsidisin et al. 2000; Ruiz-Torres and Mahmoodi 2007).

Hoffmann et al. (2013) defined 'Supply risk mitigation' as the actions used to eliminate, diminish or counteract supply risks. Identifying and developing contingency plans help firms to survive in today's competitive world. Table 13.1 gives a glimpse of the literature on supply risk mitigation strategies.

Ganguly (2013) identified that the frequently used management efforts to reduce supply risk are: forming strategic alliances, holding extra inventory, certifying suppliers, and the like. Colicchia et al. (2010) claimed that risk management strategy to be effective needs to consider the model of risk which shows when and how particular approaches are effective rather than broad-brush approaches to

Table 13.1 Summary of supply risk mitigation strategies

Reference	Risks	Method	Risk mitigation strategy/ies
Chen et al. (2013), Giannakis and Louis (2011)	Supply, demand and process risks supply and demand risks	Model development DSS—decision support system using multi-agent modelling (a sub category of artificial intelligence)	Supply chain collaboration Collaboration within supply chains, emergency procurement, informing supplier about the delay
Wang et al. (2010)	Random capacity and random yield types of supply uncertainty	Model development	Multiple sourcing
Enyinda and Gebremikael (2010)	Outsourcing risks of a pharma SC	AHP and sensitivity analysis	Reduce risk, accept risk, transfer risk and avoid risk
Liu et al. (2010)	Catastrophic operational risks	Numerical demonstrations in terms of expected profits	Dual sourcing and risk pooling
Hou et al. (2010)	Supply uncertainty in the form of recurrent yield uncertainty and DU in the form of random demand	Sequential optimization process, simulation	Buy back contract with a backup supplier
Oke and Gopalakrishnan (2009)	Supply, demand and miscellaneous risks	Case study	Collaborative planning, inventory, make-shift stores to make products available, multiple sourcing strategies including global sourcing
He and Zhang (2008)	Random yield production and uncertain demand	Profit maximization	Risk sharing contracts
Modi and Mabert (2007)	Supply risk	Variable structural equation modelling (LVSEM)	Supplier development through collaborative inter-organizational communication
Kleindorfer and Saad (2005)	Accidents in the U.S. chemical industry	Hypothesis testing, descriptive statistics	High quality process MANAGEMENT like six sigma, enterprise risk management (ERM) systems
Johnson (2001)	Demand and supply risk	Descriptive statistics	Strategic outsourcing, flexible suppliers, logistics postponement —reduced number of warehouses

manage risk. Ghadge et al. (2013) proposed that each risk should not be dealt with independently, rather risk models be used for designing strategies for the set of risk attributes. These modelling platforms are an 'early warning system' to predict risk events leading to appropriate risk control and mitigation.

Scenario modelling is proposed in this chapter which helps in understanding different forces at work and viewing uncertain and complex future from multiple dimensions. Bishop et al. (2007) recommended that it is important for us to consider the future deeply and creatively to avoid being surprised. At the same time, there is a need to be prepared for the future uncertainties. Scenarios depict multiple possible futures. A discussion on this topic may be found in Amer et al. (2013), Bishop et al. (2007), Bradfield et al. (2005).

13.3 Scenario Modelling for Risk Mitigation

Scenario techniques were developed during 1950s by the Research and Development Corporation in US. In 1970s, this technique was first used in the business community by Royal Dutch Shell Company. Amer et al. (2013), defined scenario planning as "a systemic method for thinking creatively about possible complex and uncertain futures". Scenario planning considers a variety of possible futures about many important uncertainties in the system instead of predicting one single outcome as is done in budgeting or forecasting. As claimed by Schoemaker (1995), Scenarios identify all future possibilities. They portray how multiple forces result in varied futures. Scenarios help us to consider possibilities which might otherwise be ignored. They create "memories of the future", highlighting minor signals early as the future unfolds ('prepared minds').

Scenarios can be generated using different methodologies. The popular methods are discussed by Bradfield et al. (2005) and Amer et al. (2013). These approaches of scenario planning are: (1) intuitive logics, (2) probabilistic modified trends (PMT) methodology and (3) the French approach of La prospective.

Intuitive logics approach is sans mathematical algorithm. Probabilistic approach combines classical forecasting techniques (like time series analysis) with qualitative factors. French approach of La prospective method is used for long-term planning, for better understanding of the contemporary world including hidden potentialities and dangers. Bradfield et al. (2005) found Intuitive Logics methodology better than the other two methods.

Amer et al. (2013) presented a detailed review of scenario planning literature. They found a significant increase in the use of scenario planning during the last decade. The authors claimed that scenario planning has been extensively used by multiple large public and private institutions. They observed that scenario planning approach was more popular among large-sized companies. Scenarios were

generally used for long term planning of ten years or more, and majority of scenario users were from capital intensive industries such as petroleum, aerospace, etc. The authors also observed the development of a large number of scenario building methods that ranged from simplistic to complex and qualitative to quantitative. The authors also discussed the scenario selection and validation issues.

Burinskienė and Rudzkienė (2009) showcased use of scenario planning in a complicated task of drafting the general plan of the territory of Molėtai District (Republic of Lithuania) for the sustainable development in the context of long-term economic changes taking place in society. Bishop et al. (2007) reviewed almost all the techniques, i.e. 23 variations used to develop scenarios that have been described in the literature. They also commented on their utility, strengths and weaknesses. Bunn and Salo (1993), focused managers' attention to the set of future descriptions that are feasible but not necessarily most likely. Bradfield et al. (2005) traced the origins and growth of scenarios and subsequent evolution of various methodologies. The authors classified the methodologies into three techniques, viz. 'The intuitive logics school', 'the probabilistic modified trends school' and 'the La prospective school'. They also compared and contrasted the salient features of these schools.

Peterson et al. (2003), presented examples from business (Shell Oil), government (Monte Fleur, South Africa), and conservation planning (Northern Highland Lake District, Wisconsin) illustrating the value of scenario planning. For conservation, major benefits of using scenario planning are (1) increased understanding of key uncertainties, (2) incorporation of alternative perspectives into conservation planning, and (3) greater resilience of decisions to surprise. Bunn and Salo (1993) reviewed the main aspects and developments of scenario planning and realized that aspects of scenario planning are included in most strategic planning and forecasting methods.

As revealed from the literature, scenario planning is mostly adopted by capital intensive large-sized companies for long-term planning due to availability of resources. However, in this chapter, intuitive scenario technique is adopted for short-term operational planning.

13.4 Proposed Approach

Intuitive scenarios are essentially subjective and qualitative based on disciplined intuition. It is carried out by a team of individuals from within the organization in connection with a management decision, problem or an area of general concern which can be broad or narrow in scope, ranging from industry, country, region or universe to an issue-specific matter. Experienced scenario practitioners (experts) design and facilitate the process and can be catalysts of new ideas. Generic brainstorming, STEEP analysis (social, technical, economic, environmental,

and political trends), clustering, matrices, system dynamics and stakeholder analysis are some of the commonly used tools in the Intuitive technique. It sets 2–4 equally plausible, relevant, coherent (logical), comprehensive, internally consistent scenarios to reflect the uncertainty which should result in a new and original outlook on the issues (van der Heijden 2005; Amer et al. 2013). The advantage of this method is that it compels the people in the organization to think about the worst possibilities in future, ready to face the dynamic complex world and thus be more flexible.

Scenario planning can be modified in various different ways to serve a particular context, Peterson et al. (2003). It is a versatile soft tool. The following approach of intuitive scenario technique is adopted in this work to mitigate operational supply risks.

Step 1: Decide assumptions/drivers for change

Scenario planning starts by dividing our knowledge into two broad domains: (A) things we believe we know something about; and (B) elements we consider uncertain or unknowable. Scenario planning is using the known and the unknown factors to draw a number of possibilities of the future.

In the ideal approach, the first stage should be to carefully decide the overall assumptions on which the scenarios will be based followed by defining the various drivers of change. Then brainstorm to ensure the list is complete, and selected issues are limited and important for the organization.

Step 2: Define the problem

Determine a real question at hand or a genuine concern. Specify the timescale and the stakeholders in the problem or solution.

Step 3: Build scenarios

The next step is to link these drivers together to provide a meaningful framework. Mini scenarios are formed by arranging the drivers in smaller groups. Unimportant scenarios are then eliminated and two or three most important scenarios/drivers of change are analysed. Validity test of scenarios is carried out based on logical analysis or intuitive 'gut-feel'.

The scenarios are then 'written up' in the most suitable form for use by the decision makers. Most scenarios are written in word form, especially where they are qualitative.

Step 4 Identify issues arising

The final stage of the process is to examine these scenarios to determine the most critical outcomes; the 'branching points' relating to the 'issues' which will have the greatest impact (potentially generating 'crises') on the future of the organization. The subsequent strategy will have to address these since the normal approach to strategy deriving from scenarios is one which aims to minimize risk by being 'robust'.

13.5 Illustration

Under the intuitive scenario planning approach for mitigating supply risk, an example is assumed of a pharmaceutical company having manufacturing plant in India, and marketing its own products in India. It imports active material from the global source of the parent company and buys excipients and packaging materials from Indian suppliers who are mostly the small and medium enterprises.

Step 1: Assumptions, known facts and unknown elements are as given below.
Most of the Indian suppliers have capacity constraints and limited resources. They lack commitment to customers as well as their suppliers. Stringent quality control measures are also absent in their organizations. Most of these small and medium enterprise suppliers do not have labour-friendly human resource policies and often neglect Government rules and regulations. On the other hand, lower sales forecast accuracy level of the firms result into frequent changes of the production plans.
The 'STEEP' analysis of this pharmaceutical company for the next 5 years is as follows:

S: **S**ocial: Existing diseases will continue and some new diseases will emerge; there will be new entrants in market, intensifying competition.
T: **T**echnical: Research and development continues resulting in newer, cheaper and more effective medicines; Indian medical industry to become more professional expecting promised results and deliveries.
E: **E**nvironmental: More environmental restrictions will be introduced like green production, waste reduction, reuse/remanufacturing, etc.
E: **E**conomical: More disposable income with people but at the same time more health conscious; customer will be more demanding in terms of costs and results. This also is an opportunity for new wellness products for preventive medication.
P: **P**olitical: Make in India policy of Government; Indian economy will further open up.

Step 2: The enterprise wants to ensure uninterrupted flow of supply of finished products from its production facility to the market. Therefore it is required that it receives continuous flow of input materials from its suppliers with no delays and no quality complaints in their supply.

Step 3 Following mini scenarios can be developed:

1. Everything is fine: Economic growth continues, more disposable income is available with people, society is health conscious, spends sufficient amount on heath activities, formulators are professional resulting in timely quality supplies.
2. Intensified competition: More open economy, formulators on their growth path, formulators take more orders than their capacity, India becomes hub for global production for many of the multinational firms.

All this results in some delay in supplies of input material; increased competition of the firm's products thereby requiring committed timely deliveries of the firm's products to the market.

3. Economic slowdown: Economic depression, people spend money consciously; many small-sized formulators cannot sustain and close down their businesses. The firm therefore has difficulties receiving input material on time; production planning becomes a difficult task due to reducing demand for the firm's products.

Step 4: Business in the mid-term looks very encouraging. Looking into the global position India has today and make in India policy of the Government, the future looks very bright for businesses. India can become production hub of many global pharmaceutical players. Small and medium enterprises would be in great demand.

However there can be a risk of not receiving uninterrupted supply from these suppliers as also there may be trade barriers on import of active materials. Therefore:

For high-risk suppliers, it is proposed to go for a backward integration and start own manufacturing. This will help to gain a better control over input materials which are crucial and vital for production.
For materials provided by medium-risk suppliers, it is suggested to buy from in-town vendors and develop alternate sources for inter-state vendors.

To mitigate the risk, root cause analysis should also be done as a routine practice, for example

- Variation in fill rate can be due to internal issues of the supplier like quality issues, machinery problems, labour issues, financial problems, etc. or non-receipt of input material by the supplier due to issues at tier II suppliers or non-payment of bills.
- Variation in price from suppliers can be due to change in price by tier II suppliers or change in Government taxes and duties or change in exchange rate.
- Defects in input materials can be due to faulty process at suppliers or communication gap in terms of delivery specifications or human errors of omission and/or commission.

If the exact causes are identified, the possibility of the future supply disruptions can be controlled. Although, these results are identified from the scenario planning exercise, there is a need to statically validate the same.

Figure 13.1 depicts scenario modelling followed by root cause failure analysis which is suggested for mitigation of supply risks of Indian firms.

Firms will be able to deal with uncertainties and improve their performance if they also focus on the issues discussed below. The following measures suggested to Indian firms will help them minimizing, if not overcoming, challenges in managing supply disruptions.

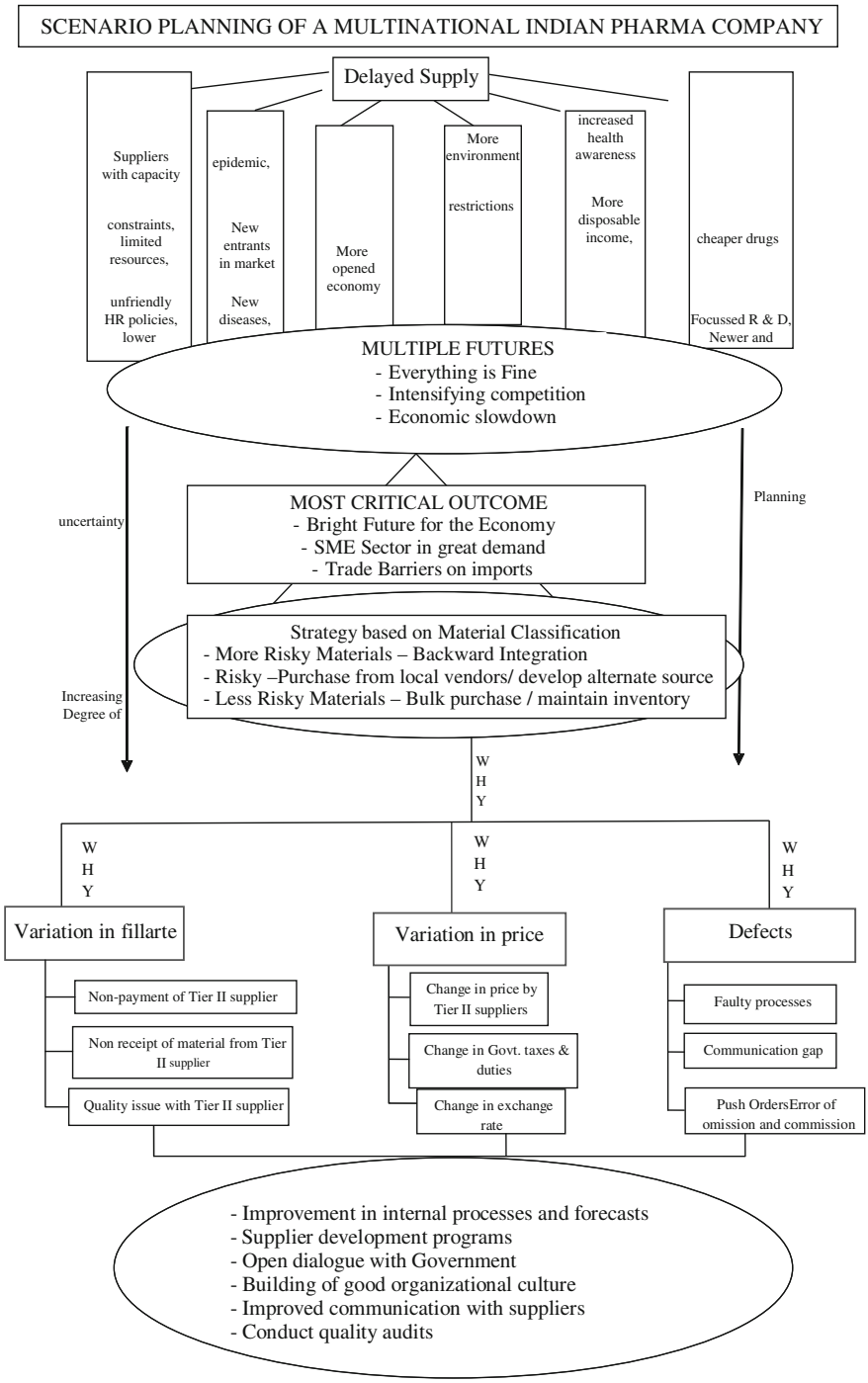

Fig. 13.1 Scenario planning

Indian firms need to consider suppliers as partners, and work with them on profit sharing basis. Supplier development programs should be implemented in the areas of technology transfer, augmenting testing laboratories, Information Technology (IT) systems, implementation of global practices like Good Manufacturing Practices (GMP), Good Warehousing Practices (GWP), subscribing to certifications like ISO, etc. Quality audits for supplier plants should be carried out regularly. Suppliers should be encouraged to follow social best practices like avoiding child labour, etc. Ketkar and Vaidya (2012).

Firms should become part of industry associations so as to be able to influence government policies. It can also help firm's suppliers to handle challenges posed by governmental policies and infrastructure. Firms should promote meritocracy and compliance. Firms can help suppliers strengthen their documentation processes. They can also play an active role in advising supplier in talent retention policies like performance-based incentive schemes and staff training programs.

Firms should have a culture of excellence, commitment and discipline. They should imbibe values like punctuality, excellence, accountability, etc. They should have a result-oriented approach, Ketkar and Vaidya (2012). The firms should also sensitize their sales and marketing departments regarding improvement in forecasting accuracy levels, which should be linked to staff's performance appraisals. They should also have internal discipline so that their short term procurement plans are not altered and therefore supplier capacities can be booked in a planned manner. Firms should have internal trainings for staff for improving disciplined approach in communication with suppliers. Supplier deliverables and other expectations should be communicated clearly. They should regularly evaluate performance of their suppliers, and monitor disruptions. Firms should also review performance of vendors to their suppliers (tier two suppliers) and have alternate plans to mitigating disruptions caused by tier two suppliers. Firms should also make efforts to develop their tier two suppliers.

In India, majority of the suppliers are small and medium firms who are not very professional. Normally there could be delays in receiving supplies of materials from these suppliers. The firm's purchase executives would therefore be very busy in fire-fighting, following up with vendors for supplies. Whenever there is a delay in receipt of material or any quality issue, they try to find quick-fixes, generally short-term solutions.

The Indian firms usually follow ineffective methods to handle supply disruptions like last-minute vendor follow-up, posting an employee at supplier location, taking random actions like delaying supplier payments, replacing vendor at the last moment, etc. It would be better to carry out root cause failure analysis (RCFA) as a routine practise in case of any delay in receipt of these materials or quality issues. This will help the executives to find the real causes for such issues, which could be incompetency of the supplier, problems with supplier's supplier, process issues at their plant, transportation issues, etc. Once the RCFA is done, the corrective measure can be taken accordingly which would help reducing the frequency of such issues.

13.6 Conclusion

Supply disruptions are faced by Indian firms regularly. This study suggests ways to mitigate supply risks of Indian firms. Since Indian management assumes the impact of supply disruption to be low, either it is ignored by the management and adjusted on the shop floor or safe blanket practices like buffer stock, multiple sourcing, etc. are followed which are inefficient. Unwanted disruptions can however be avoided using proactive strategies. Scenario modelling as a proactive measure is suggested to mitigate the risks. Firm can think through the unwanted future events, plan and work out the strategies to deal with it by blending multiple suitable approaches to remove or reduce the supply risks.

It is also recommended to analyse the information about delays in supplies to understand the reasons of disruptions in India. This study also suggests certain measures like improved coordination, disciplined approach, higher commitment levels, better employee engagement, etc. to reduce supply risk disruptions and improving operations of Indian firms.

Scenario technique is subjective in nature hence difficult to drive scenarios to optimal decisions. However this technique was born from practice and its appeal is based more on experience than scientific evidence.

Risk may not always lie with the suppliers. Manufacturer may also change orders because of lack of planning, or forecasting errors, or lack of understanding of customer requirement, etc. But this is out of the scope of this study. One needs to work out the feasibility and expected cost of these feasible scenarios of risk mitigation strategies. Application of scenario modelling can be tested in small and medium sized firms for the mid-term operational planning.

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