# CHAPTER 2

## LITERATURE REVIEW

As we are approaching towards 21st century, customer requirements are not only limited to traditional issues (such as higher quality, lower price, and so on) but it extends to the speed of delivery and variability of products (Zhou and Nagi, 2002). Success and survival of any enterprise is very difficult to ensure considering these issues. In order to become competitive in changing customer and technological requirements, manufacturers are forced to develop agile supply chain capabilities in their supply chain (Yusuf et al., 2004). The concept of agility originates from this in order to respond within specific time and to the unique needs of customers and markets. Therefore, there is a need to incorporate agility in supply chain which has drawn attention of researchers and practitioners worldwide for more than two decades. Agility is widely accepted in the manufacturing industry as a new competitive concept to become competitive. In this chapter, a rigorous study of literature is performed to walk around the concept of supply chain agility, various model and framework of agility, key parameters of agility, its dimensions, and finally research gaps were identified. A systematic inspection of literature related to supply chain agility, starting from that of 1995s to the present day, is carried out to explore and understand the perspectives of supply chain agility. An up-to-date literature review resulted into classification of different study approaches related to supply chain agility. The modelling of the enablers, agility assessment, conceptual framework, and agility implementation are discussed in detail.

### 2.1 Introduction to agility

"Agility" is the characteristic of being agile. Being agile means state or quality of being able to move quickly and in an easy fashion. The term agility refers to a firm's ability to accelerate the activities on critical path, and is, therefore, a direct indicator of a firm's

time-based competitiveness (Kumar and Motwani, 1995). Business organizations are striving to improve their supply chain performance in competitive business environment. Agility is perceived as the dominant competitive vehicle for all organizations in an uncertain and ever-changing business environment (Tseng and Lin, 2011). An agile enterprise can therefore adjust to any unexpected or sudden changes in the environment both rapidly and efficiently (Ganguly et al., 2009). Swafford et al., (2008) advocate that organizations with supply chain agility can better respond to unforeseen events. The concept of agility comprises two main components (Sharifi and Zhang, 1999; Li et al., 2009):

- Responding to anticipated and unpredicted changes in proper ways and within due time.
- Exploiting changes and taking advantage of changes as opportunities.

First component emphasizes agility in terms of change-enabling capabilities that are embedded in organizational processes and the second component highlights agility as an opportunity-seeking capability within the supply chain, as well as within its surrounding environment. Organization following these concepts of agility will enrich or satisfy customers and employees of the supply chain. Therefore, today's business organization required to possess the agile characteristics in their supply chain. Implementation of agility in supply chain will help supply chain manager to sense, perceive and anticipate changes in the business environment. Agility directly impacts the sourcing, making and delivery processes as well as the overall performance of the supply chains (Damghani and Tavana, 2013). Agility does not come for free; decision maker needs to make a considerable effort to implement agility in any kind of system. Hence, decision maker needs to choose where to focus their efforts in becoming more agile (Lankhorst, 2012).

## 2.2 Agility in supply chain

Supply chain operates in an environment of varying order quantities and varying supply lead-times. In continuously altering environment, it is very difficult for supply chains to distribute the right quantity of product, to the right place, at the right time, at the right cost. To overcome these conditions supply chain should be agile in order to respond to altering environment conditions. Agility in supply chain enables a firm to respond in a timely and effective manner to market volatility and other uncertainties; thereby allowing the firm to establish a superior competitive position (Swafford et al., 2006). Agile movement in supply chain has received much attention from the practitioners from last two decades. Great companies create supply chain in such way that it can respond to such a volatile environment. This exercise can be called as the concept of agility. The powerful integration of supply chain management and agility is known as the Agile Supply Chain (ASC) (Damghani and Tavana, 2013). Agile supply chain is the capability of a supply chain and its members to rapidly realign the network and its operations to meet the highly dynamic customer requirements (Ismail and Sharifi, 2006). Faisal et al., (2006) believe that supply chain agility is a key to inventory reduction, adapting to market variations more efficiently, enabling enterprises to respond to consumer demand more quickly and integrating with suppliers more effectively. Hence executing agility in supply chain is essential in order to survive in an uncertain and ever-changing business environment. Implementing agility in supply chain provides various features to supply chain (Yusuf et al., 1999). These features are:

- High quality and highly customised products
- Products and services with high information and value-adding content
- Mobilisation of core competencies
- Responsiveness to social and environmental issues
- Synthesis of diverse technologies

- Responsiveness to change and uncertainty
- Intra-enterprise and inter-enterprise integration

Various definitions of supply chain agility have been advocated in the literature. These definitions do not contrast with each other and almost all of them reflect the same meaning of the concept. Table 2.1 show some selected definitions of supply chain agility tabulated from the literature.

Table 2.1: Some selected definition of supply chain agility

| **Reference** | **Definition of agility** |
|---|---|
| Kumar and Motwani (1995) | A firm's ability to accelerate the activities on the critical path |
| Vokurka and Fliedner (1998) | Capability of responding to change in a dimension beyond flexibility. |
| Naylor et al. (1999) | Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. |
| Christopher (2000) | The ability of an organisation to respond rapidly to changes in demand, both in terms of volume and variety. |
| Sharifi and Zhang (2001) | Ability of an organization to sense, perceive and predict changes in the business environment. |
| Aitken et al. (2002) | Agility is an ability to have visibility of demand, flexible and quick response and synchronized operations |
| Brown et al. (2003) | Ability to respond quickly and effectively to changes in market demand |
| James (2005) | Ability to respond to change, uncertainty and unpredictability in the business environment, whatever its source-customers, competitors, new technologies, suppliers or government regulation |
| Swafford et al., (2006) | Capability to adapt or respond in a speedy manner to a changing marketplace environment |
| Agarwal et al. (2007) | Agility is the fundamental characteristic of a supply chain needed for survival in turbulent and volatile markets. |
| Li et al., (2008) | It is the supply chain's alertness to internal and environmental |

| | |
|---|---|
| | changes and the supply chain's capability to use resources in responding to these changes in a timely and flexible manner. |
| Braunscheidel and Suresh, (2009) | Organisation's capability, in conjunction with its key suppliers and customers, to swiftly and effectively react to changes in its environment. |
| Tseng and Lin, (2011) | Ability of an enterprise to respond rapidly to changes in the market and customer demands. |
| Gligor and Holcomb, (2012) | Ability to quickly adjust its supply chain tactics and operations. |

## 2.3 Relationship of agility to other concepts

There are several terms which contain similar meaning and are used interchangeably for agility. These terms are leanness, flexibility, adaptability, resilience. Before further proceeding to the literature of agility, it is important to understand the differences between agility and other concepts. Differentiations are needed to gain a deeper understanding of agility. This section provides clear definitions for agility and other related concepts.

### 2.3.1 Agility and leanness

There are huge discussions on agility and leanness in the literature which take away confusion over these paradigms. Agile concept was coined by Iacocca Institute while lean concept is firstly developed and applied by Ohno (1998) at Toyota Motor Corporation in Japan with two main pillars automation and Just-in-Time (JIT) production (Putnik and Putnik, 2012). After first introduction both the concepts have been described in many books around the world. There are number of definitions available on the agility and leanness in the operations management literature. Since some definitions of agility already explained in section 2.2, the few selected definitions of leanness are given in Table 2.2.

Table 2.2: Some selected definition of Leanness

| Reference | Definition of Leanness |
|---|---|
| McLachlin (1997) | Extent to which certain JIT flow and quality practices are implemented. |
| Naylor et al. (1999) | Developing a value stream to eliminate all waste, including time, and to enable a level schedule |
| Phillips (1999) | Philosophy of waste elimination, the removal of all non-value added activity from the process of delivering a customer's requirement |
| Hopp & Spearman (2004) | Production that is accomplished with minimal buffering costs |
| Agarwal et al. (2006) | Lean is about doing more with less. |
| Narasimhan et al. (2006) | It is accomplished with minimal waste due to unneeded operations, inefficient operations or excessive buffering in operations. |
| Krishnamurthy and Yauch (2007) | Eliminating waste in waiting time, transport, inventories, and defects, and focuses on a level production schedule. |

Literature on agility and leanness paradigms believes that the two strategies are distinct and that agility is an improvement to leanness (Browaeys and Fisser, 2012). Being “agile” includes that the organization is able to respond rapidly to changes in demand whereas lean focuses on doing more with less, to be efficient (Christopher, 2000). In agile supply chains the focus is the ability of comprehension and rapid response to market changes whereas in lean supply chains the focus is on waste elimination (Carvalho et al., 2011). An ideal agile supply chain will meet the customer’s demand immediately with flexibility, a top quality product and at the highest level of service possible whereas an ideal lean supply chain will have zero defects in production, zero overproduction and unnecessary processing capacities, no inventories, no unnecessary movement of people and goods, and

employees will never need to wait (Bezuidenhout, 2016). Production of manufacturing organization can be agile as well as lean. Hallgren and Olhager (2009) advocate that production is agile if it efficiently changes operating states in response to uncertain and changing demands, placed upon it while production is lean if it is accomplished with minimal waste due to unneeded operations, inefficient operations, or excessive buffering in operations. Apart from these discussion about both the paradigms Table 2.3 shows comparison of agile and lean supply chains on the basis of some key characteristics. From Table 2.3 and above discussion it is clear that these two are totally dissimilar paradigms.

Table 2.3: Comparison of agile and lean supply chains

| **Distinguishing characteristic** | **Agile supply chain** | **Lean supply chain** | **Reference** |
|---|---|---|---|
| Basic definition | Respond to uncertain and changing business environment | Eliminate all non-value added activities | Cabrita et al., (2016) |
| Priority | Speed is the priority | Cost is the priority | Soni and Kodali, (2012) |
| Customer requirement | High variety of products preferred | Lower variety of products | Soni and Kodali, (2012) |
| Market demand | Unstable and Volatile | Stable and Predictable | Bruce et al., (2004) |
| Focus | People and Information | Technology and Systems | Sharp et al., (1999) |
| Profit margins | High | Low | Mason-Jones et al. (2000) |
| Information enrichment | Obligatory | High desirable | Mason-Jones et al. (2000) |
| Robustness | Essential | Arbitrary | Agarwal et al., (2006) |
| Eliminate muda | Desirable | Essential | Agarwal et al., (2006) |
| Robustness | Essential | Arbitrary | Purvis et al., (2014) |

### 2.3.2 Agility and flexibility

Contemporary manufacturing organizations have closely recognized the desirability of certain system properties such as flexibility and agility for potential competitive advantage (Giachetti et al., 2003). Flexibility and agility both are the multi-dimensional concepts. Although there are significant differences between agility and flexibility, many organisations are using these terms interchangeably (Fayezi et al., 2015). This is due to reason that content of the terms flexibility and agility have overlapping notions. For example Gerwin (2005) defined flexibility as the ability to respond effectively to changing circumstances whereas McGaughey (1999) defined agility as the ability of an enterprise to respond quickly and successfully to change. These two definitions seem almost identical, except that agility emphasizes quickness. Hence from the above definition of the agility and flexibility, it can be concluded that flexibility is the ability to react to changes and agility is the speed in responding to the change (Gong and Janssen, 2012). Agility and flexibility are distinct concepts where flexibility is an antecedent of agility (Swafford et al., 2008). This section elaborates more in-depth understanding of the concepts of flexibility and agility in order to differentiate both of them.

According to Fayezi et al., (2015) supply chain agility is a strategic ability that assists organisations to rapidly sense and initiates a response, whereas supply chain flexibility refers to an operational ability that assists organisations to efficiently generate change internally and/or across their key partners against internal and external uncertainties. It has been recognized that a system can be flexible without being agile, while an agile system is definitely flexible (Prahalad and Hamel, 1990). Researchers working on flexibility aspects have found that flexibility leads to the imparting of agility in the organisations (Yusuf et al. 2003). Flexibility is a key characteristic of an agile organisation. In that respect, the origins of agility as a business concept lie partially in flexible manufacturing systems (Christopher

and Towill, 2001). Flexibility is concerned about what kind of processes should be designed, what kind of resources should be obtained and what investments should be made to reduce time, cost or performance penalties to adjust to changes while agility is more specifically about whether the organization has made investments that are aligned with the competitive demands of the environment (Chiang et al., 2012). With the above discussion it is clear that the two terms are distinct concepts, with flexibility being a dimension of agility.

### 2.3.3 Agility and adaptability

Adaptive nature of supply chain is found essential in order to become agile organization. Adaptability is the firm's ability to correctly predict and appropriately adapt to an unexpected change in the business environment (Takii, 2007). To identify and capitalize emerging markets and technology opportunities, firms should have ability to deal with new environmental conditions. The ability to deal with new environment conditions is known as firm's adaptive nature. Literature claims that agility and adaptability are different properties of supply chain. Only very few researchers have conceptually distinguished between supply chain agility and supply chain adaptability (Eckstein et al., 2015). This is due to reason that scholars have largely focused on supply chain agility, as a result, there is a lack of a solid research basis on supply chain adaptability, making it difficult to compare and accumulate results and arrive at meaningful conclusions. Lee (2004) states that agility in supply chain is the ability to react quickly to unexpected or rapid shifts in supply and demand, while adaptability means adjust its own supply chain design to meet structural shift in markets and modify supply networks to strategies, products, and technologies. From argument of Lee (2004) it is clear that adaptability is an approach to make supply chain agile. Supply chain agility emphasises the speed of response, while supply chain adaptability emphasises innovativeness (Eckstein et al., 2015). Agility relates to the

interface between the company and the market whereas adaptability is a feature of the company's production system. Katayama and Bennett (1999) advocate that agility is a set of abilities for meeting widely varied customer requirements in terms of price, specification, quality, quantity and delivery, while adaptability is the inherent ability to adjust or modify its cost performance according to demand. This dissertation considers agility and adaptability as distinct concepts, with adaptability as an enabler of agility.

### 2.3.4 Agility and resilience

Supply chain operates in an uncertain environment. Supply chain management must adopt different and more innovative strategies that support a better response to customer needs in an uncertain environment. An important aspect for all supply chain managers is the capacity of their supply chain to withstand upheavals, disruptions and unforeseen events (Brusset and Teller, 2017). To achieve this aspect, supply chain has to be more agile as well as be more capable of coping with disturbances; meaning that supply chains has to be more resilient. The simultaneous deployment of agile and resilient approaches will enhance supply chain performance and competitiveness (Carvalho et al., 2012). Before coming to the point, it is necessary to go through the story of resilience since agility is already explained. Resilience is a term that has been used for a long time among the practitioners. Resilience is defined by oxford dictionary as the capacity to recover quickly from difficulties. In the context of supply chain also it contains similar meaning. Supply chain resilience is the ability of a system to return to its original state or move to a new or more desirable state after being disturbed (Christopher and Peck, 2004).

Agility and resiliency are two sides of a single coin which can be called as adaptive capacity. Adaptive capacity means capable of coping with the uncertain business environment. Both agile and resilient approaches influence performance and

competitiveness of supply chain. Agility is as an integral counterpoint of resiliency. Although few researches refer both the concepts as the means of improving supply chain performance, they do not provide an overview on the differences between them. This section tries to fill this gap. Ponomarov and Holcomb (2009) describe agility as one of the most powerful ways of achieving resilience in the supply chain. According to Camarinha-Matos (2014), agility represents the ability to quickly and effectively cope with unexpected changes in the business environment whereas resilience is the ability of a system to cope with severe disturbances or disruptions and return to its original or desired state. In other words agility is the capability to take advantage of the changes while resilience is the ability to repair or reconstitute lost capability or performance after damaging perturbations in the business environment. The driving force of agility is the changing environment whereas the driving force of resilience is disruption that can originate in the supply chain or the business environment (Lenort and Wicher, 2012). Carvalho et al., (2012) believe that, the agile approach pursues the responsiveness of the supply network, but the resilient approach seeks to avoid/minimize the negative effects of disturbances.

## 2.4 Classification of literature on agility

Literature on supply chain agility can be broadly classified under different categories which are structural modelling of the enablers, conceptual framework, agility evaluation, agile supply chain management, agility implementation and leagility. Brief explanations of each are as follows:

### 2.4.1 Modelling the enablers

There are number of important characteristics that a supply chain should have in order to be truly agile. These characteristics can be called as Agile Supply Chain (ASC) enablers. Many researchers have identified and explained these characteristics. For example the key

characteristics of an agile supply chain have been shown by Harrison et al., (1999) are market sensitive, virtual, network-based and process integration (Figure 2.1).

- *market sensitive*: it is closely connected to end-user trends
- *virtual*: it relies on shared information across all supply chain partners
- *network-based*: it gains flexibility by using the strengths of specialist players
- *process aligned*: it has a high degree of process interconnectivity between the network members

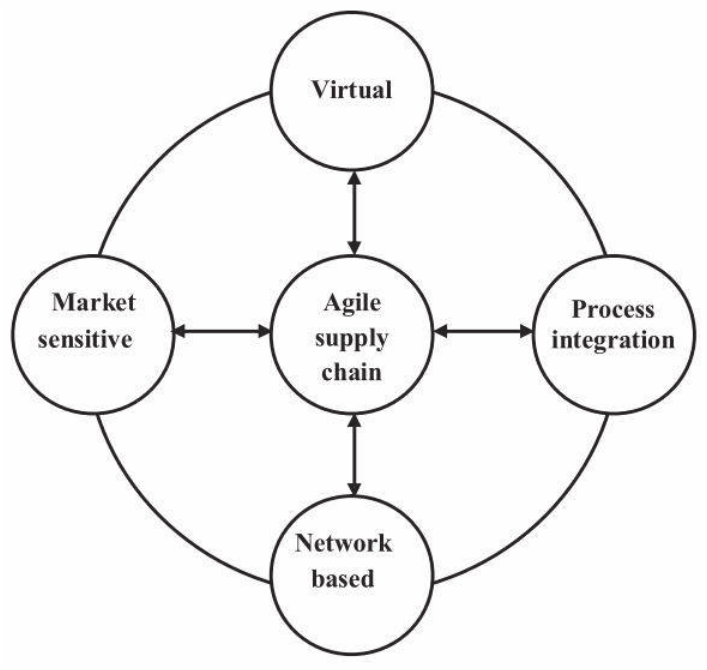


Figure 2.1: Characteristics of an agile supply chain [adopted from Harrison et al., 1999]

Modern supply chains are very complex in nature. It becomes very difficult for decision maker to deal with such type of a complex system in which structure is not clearly defined. Hence, it is required to develop systematic structure within a system's characteristics. Modelling the enablers of agile supply chain is the development of a methodology which provides a hierarchy of the ASC enablers. For modelling the enablers of ASC, Interpretive Structural Modelling (ISM) can be used.

ISM has been used by enormous researchers for developing systematic structure of variables from the different region but there are only few researchers who have used ISM for modelling the ASC enablers. From that Agarwal et al., (2007) were the first who have derived interrelationships of the enablers of supply chain agility. They have identified 15 enablers from the literature related to supply chain agility and assessed their importance through a case study and an ISM approach. Next contributions in this area were given by Hasan et al., (2009) by introducing and investigating 11 agility enablers. They have tried to bridge the gap by comprehensive investigation and developing the systemic relationship among agility enablers. Pandey and Garg (2009) selected 36 variables that help in making the supply chain more agile. These 36 variables are further shortened in 12 agility enablers by grouping similar types of variables together. Considering the 12 enablers they have developed a hierarchy of enablers that would help to impart agility in the supply chain. The problem with these entire models is that their models are with huge number of variables that increase model complexity and thus become difficult for managers to understand. This problem is solved by Mishra et al. (2012) and Sharma and Bhat (2014) with overview of the various enablers involved in an ASC and their relative importance. In their model they have compressed ASC enablers to seven enablers which reduced model complexity and thus make it convenient for managers to understand.

### 2.4.2 Agility assessment

One of the research agenda in agile manufacturing is the assessment of agility in supply chain. The assessment of agility in supply chains is quite important as it is an indicator of strategic agile position (Vinodh & Prasanna, 2011). Agility assessment reveals the strategic agile position of an organization in the competitive business environment (Vinodh et al., 2010). There are wide varieties of agility measurement methodologies that have been reported in literature. Some researchers have used agility performance metric to assess

agility while some of them have used Fuzzy Association Rules Mining (FARM). Some authors have defined a Fuzzy Agility Index (FAI) for the evaluation of agility by aggregating fuzzy ratings and fuzzy weights of agile capabilities, whereas some of them have used Grey Relation Approach (GRA) for calculation of agility. Some emphasize agility across supply chains, while others focus on individual business units. Some focus solely on internal operational measures and ignore the business environment. Some are strictly qualitative, and others have a mixture of qualitative and quantitative measures (Yauch, 2011). Figure 2.2 shows some important agility measurement methodologies identified from the literature. Out of all these methodologies fuzzy logic approach was the very famous technique among practitioners. This is due to fact that, compared to other techniques fuzzy logic approach has capability to handle vague and uncertainty situations (Vinodh et al., 2013).

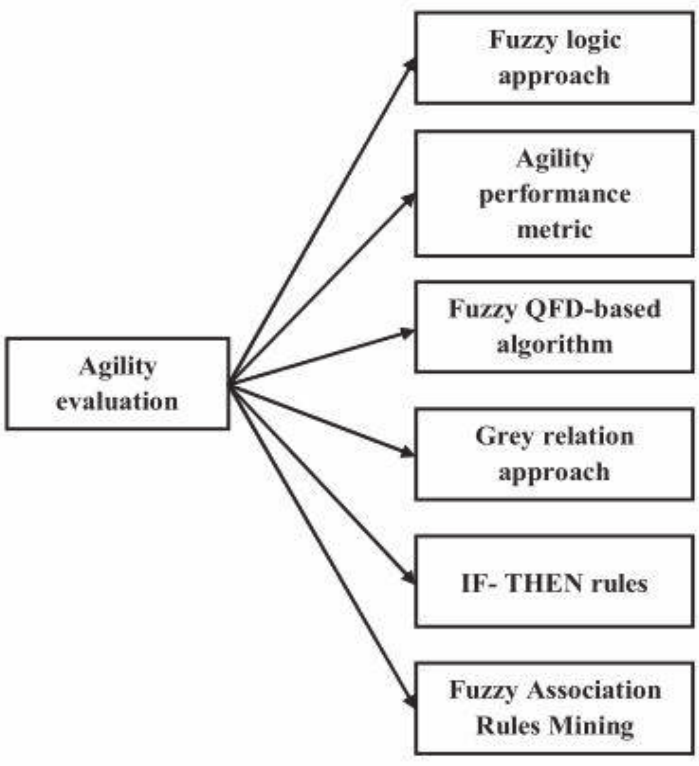


Figure 2.2: Approaches used in literature for calculation of agility

Kumar and Motwani, (1995), were the first researchers to develop a model for measuring agility. A strategic framework has been developed by them that will allow companies to systematically evaluate their effectiveness on the dimensions of agility. On the way of the determining the effectiveness of a firm, authors have developed a measure called the Agility Index (AI) which provides the composite value of the strategic agility position of a firm on a percentage scale. After them next significant contribution is given by Sharifi and Zhang, (1999) in the direction of agility assessment. They have proposed a scoring model for determining agility need level. A questionnaire survey is done by them to carry out a general study of agility drivers, the strategies and capabilities adopted by manufacturing companies. This model enables an organization to identify the strengths and weaknesses of the areas practiced towards realizing its potential of achieving agility.

Tsourveloudis and Valavanis, (2002) proposed a framework which provides the fundamentals of an adaptive knowledge-based methodology for the measurement of agility. Enterprise agility is computed using IF-THEN rule based interface method. The disadvantage of this method is that, it converts problems into complex mathematical equations which are very difficult to solve by the industrial experts. Fuzzy logic based assessment methodology is proposed by Lin et al., (2006a) for agility evaluation. They have developed a Fuzzy Agility Index (FAI) which comprises attribute' ratings and corresponding weights, and is aggregated by a fuzzy weighted average. They have tested this method on Taiwan based IT products company to illustrate the efficacy of the method. This evaluation demonstrates that the method can provide analysts with more reliable information for decision making. A new approach developed by Jain et al., (2008) which is based on Fuzzy Association Rule Mining incorporating fuzzy framework coupled with rules mining algorithm to support the decision makers by enhancing the flexibility in making decisions for evaluating agility in supply chains with both tangibles and intangibles

characteristics. They demonstrated the efficacy and intricacy of the proposed approach for finding fuzzy association rules for evaluating agility with the help of a numerical example. The next important contribution in this field is that of Bottani, (2009) who proposed Quality Function Deployment (QFD) based approach to enhance agility of enterprises. This paper aims by linking competitive bases, agile attributes and agile enablers, to identify the most appropriate enablers to be implemented by companies starting from competitive characteristics of the related market.

Yauch (2011) proposed Agility Performance Metric as a measure of agility. He has constructed a quantitative, objective metric for agility performance that assesses agility as a performance outcome, capturing both organizational success and environmental turbulence and applicable to manufacturing organizations of all types. Proposed methodology for assessing agility was based on strong theoretical foundations and could easily be applied to various levels in the organization with slight modification. Mishra et al., (2013) have developed an agility evaluation approach called, Grey relation approach, to determine the most suitable agile system for implementing mass customization (MC) strategies. Grey relation approach is a simple mathematical technique useful in situations where the information is not known precisely. Vinodh et al., (2013) reported an ASC assessment model in order to assess the performance of agile supply chain. The research was begun by identification of ASC enablers and their supporting criteria and attributes through literature review. Their agility evaluation model consists of five agile enablers, twenty criteria and eighty six attributes. The computation was performed using fuzzy logic approach. Finally their model was tested by conducting a case study in an automotive manufacturing company situated in India. Routroy et al., (2015) have given a methodology for measuring agility of the enterprise by combining the fuzzy synthetic extent of Agile Manufacturing Enablers (AMEs) weights and the average fuzzy performance ratings of the

AMEs. They have determined the agility level of a manufacturing system along different timelines.

### 2.4.3 Agility implementation

Modelling the agility enablers provides the decision maker with an opportunity to understand focal areas that need attention to make supply chain more agile whereas the assessment of agility in supply chains is the indicator for supply chain manager to know where supply chain agility stands. It is not sufficient for decision maker to know the focal areas of supply chain agility as well as to know the agility level. In addition to that it is necessary for decision maker to work on focal areas of supply chain agility to increase the agility level of supply chain. Agility implementation is one of area which gives an idea for the decision maker to know how to implement agility in supply chain. Many organizations aspire to adopt agile processes to take advantage of the numerous benefits that they offer to an organization (Sidky et al., 2007). It is well known that, as the time passes on, markets competition are getting much more severe, and hence it is becoming imperative to construct a highly efficient agile manufacturing system in order to survive.

There is very little work available in the literature related to agility implementation. Gunasekaran (1998) proposed a conceptual framework for the development and implement agility in supply chain. This framework considered customization and system integration with the help of seven enablers of agile manufacturing which are virtual enterprise formation tools/metrics; physically distributed teams; rapid partnership formation tools/metrics; concurrent Engineering; integrated product/production/business information system; rapid prototyping tools; and electronic commerce. He believes that for the design and implementation of agile manufacturing systems, firms need to bring all the enablers of agile manufacturing together so that the system is able to adapt to changing market conditions. Zhang and Sharifi (2000) presented conceptual model for implementing agility

in industry. Based on the model, a methodology for implementing agile manufacturing in industry has been proposed. Industrial questionnaire surveys and case studies were carried out to support and validate the proposed methodology. Results derived from the case studies show that the proposed methodology is able to help manufacturing enterprises formulate strategic policies in their pursuit of agile manufacturing. Elkins et al., (2004) suggested two decision models to develop and implement agile manufacturing system in the automotive industry. Their decision models provide initial insights and industry perspective into the business case for investment in agile manufacturing systems. Both the models were applied to study the hypothetical decision of whether to invest in a dedicated, agile, or flexible manufacturing system for engine and transmission parts machining. The two decision models developed are simple, capture the important features of economic decisions about manufacturing systems, and facilitate discussion with automotive industry engineers about agile and flexible machining systems.

Sidky et al., (2007) proposed agile adoption framework and an innovative approach, to implement this framework in supply chain. The framework consists of two components, which are an agile measurement index and a four-stage process. These two components together guide and assist the agile adoption efforts of organizations. Agile measurement index encompassed various agile levels that were used to identify the agile potential of projects and organizations. On the other hand, four-stage process helps to determine whether or not organizations are ready for agile adoption and what set of agile practices can and should be introduced to guide their potential. Zhang (2011) proposed a framework for the implementation of agility as a manufacturing strategy and described the development and analysis of a numerical taxonomy of agility strategies using the framework. The taxonomy was developed by clustering a number of U.K. manufacturing companies according to relative importance they place on seven agility capabilities:

proactiveness, responsiveness to changes, flexibility, quickness, competency, customer focus and partnership. Three distinct clusters of strategy groups were observed across the industry studied which are as follows:

- **Quick players:** Quick Players are oriented towards a strong customer focus and quickness. They do not emphasize flexibility and responsiveness to changes and they give low priority to proactiveness and partnership.
- **Responsive players:** Responsive Players are preoccupied with flexibility and responsiveness to changes. They do not emphasize proactiveness and partnerships and they attach low importance to quickness.
- **Proactive players:** Proactive Players are characterized by high priorities on proactiveness and customer focus, high values attached to all capabilities, and high importance given to partnerships.

### 2.4.4 Conceptual framework

From the literature perspective agility has been addressed using different approaches. Conceptual framework is one of them. Conceptual frameworks of supply chain agility are required to know and understand the subject matter deeply. They provide deep insight on the matter concerned. The Iacocca Institute was the first to outline the conceptual details of agility in 1991. There are number of conceptual framework of supply chain agility available in literature, few of them are explained below.

Sharp et al., (1999) proposed a conceptual model, based on joint research, which has been developed to identify where UK's best practice companies are in their quest to become agile manufacturing organisations. In order to validate the conceptual model it was decided to use a questionnaire which would be completed by leading UK manufacturing companies, identified by the Department of Trade and Industry, as practitioners of best practice. A methodology for achieving agility in manufacturing organizations is developed by Sharifi and Zhang (2001). The proposed methodology was applied in two

manufacturing companies and data collected from the applications were used to validate the methodology. This study provided a brief summary of the methodology and details of implementation and validation in the two case examples. Practices were proposed to support the achievement of agility in the two organizations. Yusuf et al., (2004) studied the nature of an agile supply chains and explores some of its attributes and capabilities. The study was driven by a conceptual model, which relates supply chain practices to competitive objectives. Multiple regressions were conducted to study the relationship amongst the selected variables. The results validate the proposed conceptual model and lend credence to current thinking that supply chain integration is a vital tool for competitive advantage.

Next conceptual framework is developed by Bustelo and Avella (2006), who attempted to analyse the drivers, practices and results of agility through exploratory research in order to offer an initial approach to agile manufacturing. Exploratory research work was based on case study methodology. An agile manufacturing conceptual model has been drawn up and a number of hypotheses inferred by the authors. This work confirms the suitability of case study methodology in the early stages of research, especially for drawing up hypotheses. The study presented here is of an exploratory nature and the conclusions drawn from it offer possible routes for future research in the field of agile manufacturing. Swafford et al., (2008) developed a conceptual framework to better understand the direct and indirect relationships among IT integration, supply chain flexibility, supply chain agility, and competitive performance. Using empirical data, they have found a domino effect among IT integration, supply chain flexibility, supply chain agility, and competitive business performance. Results from their study indicate that IT integration enables a firm to tap its supply chain flexibility which in turn results in higher supply chain agility and ultimately higher competitive business performance. Finally they have concluded that firms should

invest first in IT for integrating information before investing in flexible processes, additional research is needed. A model developed by Ngai et al., (2011) is based on the resource-based view. Authors have employed a multi-case study method in their exploratory research. Their findings highlight the importance of distinguishing the difference between supply chain agility and supply chain competence and their impact on firm performance. This study contributes to the growing body of conceptual and empirical literature on supply chain agility and adds to the understanding of the complexity of supply chain competence. Liu et al., (2013) proposed a conceptual framework to examine how IT capabilities (i.e., flexible IT infrastructure and IT assimilation) affect firm performance through absorptive capacity and supply chain agility in the supply chain context. With the help of survey data, result has shown that absorptive capacity and supply chain agility fully mediate the influences of IT capabilities on firm performance.

### 2.4.5 Maximizing agility in supply chain

The overall objective of any organisation is to maximise its agility. The agility of any organisation will depend upon, how well effective management of input resources like estimated cost, management hour and labour hour are available to implement agility in the supply chain. However, the existing literature on maximization of agility has failed to sufficiently address the relevant perspectives. As per the author of this dissertation, there is only one model, developed by Saleeshya and Babu (2011), available in literature which attempts to maximize agility in supply chain. The framework developed by them consists of various agility enablers in a hierarchical form. Most important enablers with respective ranks were obtained viz. AHP, OARM and DEA method. Rank of enablers is used to calculate the agility score of each enabler. For this purpose, appropriate notional values were assigned by authors to each rank position, a value of 20 to rank 1, 15 to rank 2, 10 to rank 3 and 5 to rank 4. Using these scores, a GP model is developed to maximize agility of

supply chain deploying the input resource limitations. In GP model the overall agility scores of each enabler is linked with input resource limitations such as estimated cost, available management hours and available employee hours. Specific set of input resources for each enabler and total yearly budgeted resources are considered to solve the problem. The result obtained is an indication of the degree of focus of these enablers in the respective organisations.

### 2.4.6 Leagility

Lean Production and Agile Manufacturing are currently two popular methods of production in manufacturing organization. Leanness and agility paradigms can sometimes effectively be integrated to capitalize the benefits of both paradigms. The combined approach of lean and agility paradigms are known as Leagility. Combination of lean and agile concepts gives an advantage of faster responses to market demand with less manpower, material and machines (Vinodh and Aravindraj, 2013). A leagile system has the characteristics of lean as well as agile paradigm, acting together in order to exploit market opportunities in a cost-efficient manner. Both the paradigms can be combined via a decoupling point. The decoupling point is the point in the material flow streams to which the customer's order goes through (Mason-Jones et. al., 2000). The block diagram representation of lean supply, agile supply and leagile supply are shown in Figure 2.3. In leagile supply, lean manufacturing approach can be adopted at upstream of the decoupling point whereas simultaneously agile manufacturing approach can be adopted at downstream of the de-coupling point; lean manufacturing approach enabling cost effectiveness at upstream chains while agile manufacturing capable of delivering high service levels in volatile marketplace at the downstream chains.

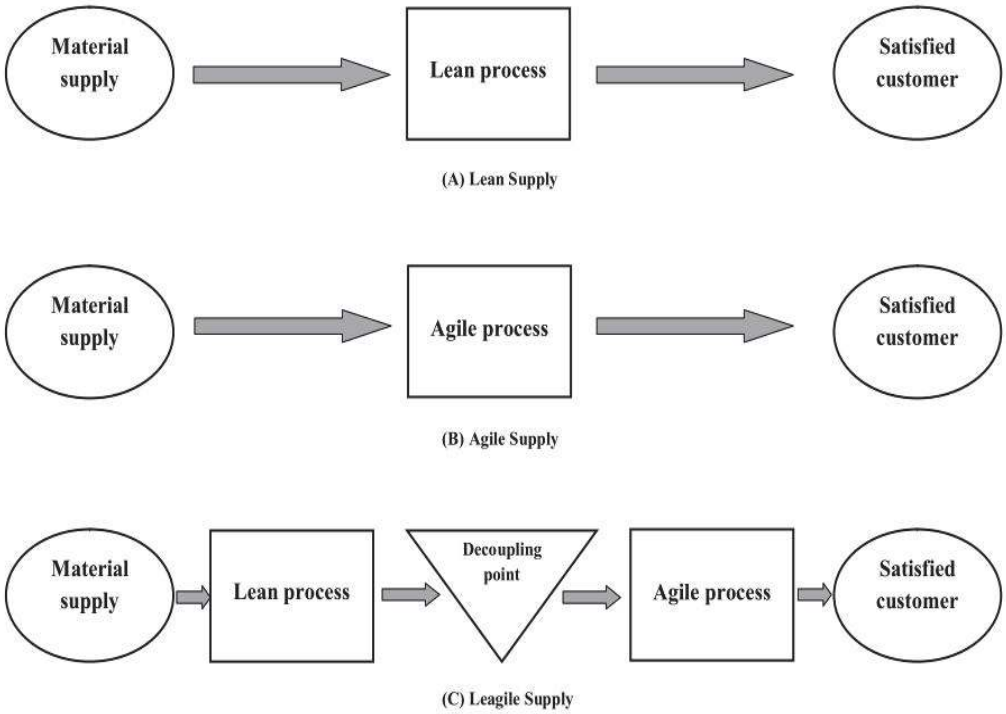


Figure 2.3: lean, agile, and leagile supply, [Source: Mason-Jonesc et al., (2000)]

There are only few researchers, who have really contributed in the domain of leagile supply chain. Though, literature available in the domain of leagile supply chain is limited, it has been found rich enough in delivering in-depth understanding of leagile concepts in supply chain management. Among them Naylor et al. (1999) was the first, who started a work towards the combination of agility and leanness paradigms into leagility. They conducted their work on measuring the performance of supply chains using this leagility concept considering market demand and lead time reduction, eliminating wastages and making improvements in scheduling. A case study is presented by them to demonstrate how agility and leanness have been combined successfully within one supply chain to meet customer requirements. The authors also have compared the lean and agile manufacturing paradigms to highlight similarities and differences between them. They have concluded that neither paradigm is better nor worse than the other, indeed they are complementary within the correct supply chain strategy. After Naylor et al. (1999), Mason-Jones et al.

(2000) are the one who proposed a leagile model in which the lean and agile systems operate at different points in a manufacturing supply chain. They have analysed the lean, agile and `leagile' paradigms and their roles in tackling differing marketplace uncertainty scenarios. A key element of this model is a 'decoupling point', which separates the lean processes from the agile processes in the supply chain. The position of the decoupling point has an effect on determining the structures of the supply chains, and hence one could decide when and where to adopt leanness or agility. They have conducted case studies illustrating the approach and representing real-world supply chains in three different market sectors.

Stratton and Warburton (2003) explored the role of inventory and capacity in accommodating the lean as well as agile supply chain variation and identified how Theory of Inventive Problem Solving (TRIZ) separation principles and Theory of Constraints (TOC) tools might be combined in the integrated development of responsive and efficient supply chains. Agarwal et al., (2006) presented a framework for modelling performance of lean, agile and leagile supply chain on the basis interdependent variables. The framework proposed by them provides an aid to decision makers in analyzing the variables affecting market sensitiveness, process integration, information driver and flexibility in lean, agile and leagile supply chains for the performance improvement of a case supply chain. Chan and Kumar (2009) proposed a new Hybrid Chaos-based Fast Genetic Tabu Simulated Annealing (CFGTSA) algorithm to solve the complex scheduling problem prevailing in the leagile environment. Proposed algorithm deals with the various aspects of leagile supply chain modelling and also focuses on the role of modern optimization methods in enhancing the performance of the supply chain. A case study is conducted by Huang and Li (2010) on the supply chain of a personal computer manufacturer in Taiwan to achieve leagility through reengineering its supply chain. With the help of case study, authors have shown

how the company adjusts its production processes from Build-to-Order (BTO) to Configuration-to-Order (CTO) to achieve leagility. Case study also helped to identify the processes employed and the problems faced in the process of realizing leagility. Vinodh and Aravindraj (2013) have presented the conceptual model of leagility estimation with lean and agile principles. A multi grade fuzzy logic approach has been used for the evaluation of leagility in supply chains. They have conducted case study in an Indian transformer manufacturing organisation to compute the performance of supply chains using both lean and agile concepts as leagility supply chains.

**2.5 Dimension of agility**

The current business environment is full of constant change, shorter product lifecycles and uncertainties in demand and lead times. It is very difficult for manufacturing organization to survive and prosper in such type of business environment until and unless the multidimensionality concept of agility is fully explored. Hence it is necessary for decision maker to know about all the dimensions of agility. The identification and classification of the dimensions of agility enables the development of underlying structure of an agile supply chain. Dimension of agility is called with different names among the practitioners such as agile metrics, agile capabilities and supply chain characteristic. Dove (1995) called it as proficiency metrics of agile supply chain. He believes that agile companies are those that respond successfully based on four change-proficiency metrics. These metrics are cost, time, robustness and scope. Goldman (1995) proposed that enriching customer and cooperating to enhance competitiveness were important dimensions of agility. Some authors from literature called dimensions of agility as agile capabilities. Agility capabilities include the capabilities which should be provided in an organization in order to create enough responsiveness for the changes (Sharifi and Zhang, 1999). Carvalho et al., (2012) called it as supply chain characteristic across agile approach. They have suggested six

characteristics which influence the supply chain behaviour supporting the quick response to changes in demand in terms of volume and variety.

Table 2.4: Dimension of agility from literature prospective

| Authors | No. of Dimensions of agility | Dimension of agility proposed by authors |
|---|---|---|
| Dove (1995) | 4 | Cost, time, robustness and scope |
| Sharifi and Zhang (1999) | 4 | Responsiveness, competency, flexibility, quickness |
| Lin et al., (2006a) | 4 | Responsiveness, competency, flexibility, quickness |
| Zhang and Sharifi (2007) | 7 | Proactiveness, responsiveness, competency, flexibility, quickness, focusing on customer, partnership |
| Jain et al., (2008) | 4 | Responsiveness, competency, flexibility/adaptability, quickness/speed |
| Tseng and Lin (2011) | 4 | Responsiveness, competency, flexibility, quickness |
| Yaghoubi et al., (2011) | 3 | Responsiveness, competency, quickness |
| Zhang (2011) | 7 | Proactiveness, responsiveness, competency, flexibility, quickness, customer focus, partnership |
| Carvalho et al., (2012) | 6 | Flexibility, velocity, responsiveness, competence, visibility, collaboration |
| Gligor et al., (2013) | 5 | Alertness, accessibility, decisiveness, swiftness, flexibility |

Gligor et al., (2013) filled the gap related to the ambiguity surrounding the dimensions and definitions of firm supply chain agility by employing a multidisciplinary literature review to gain an in-depth understanding of agility. They have developed a comprehensive

conceptualization and measurement scale of firm supply chain agility that explored the multidimensionality concept of agility. They have suggested five distinct dimensions of agility including alertness, accessibility, decisiveness, swiftness, and flexibility. These dimensions were examined as potential firm supply chain agility dimensions. Some of the dimensions of supply chain agility as described in the literature are being tabulated in Table 2.4.

**2.6 Enablers of agility**

To be truly agile, a supply chain must possess a number of distinguishing characteristics (Sharma and Bhat, 2014). These characteristics can be called as agile supply chain enablers. Agile manufacturing paradigm requires a systematic study of its enablers to aid in successful adoption and implementation of the concept and practice of agility (Hasan et al., 2009). Enablers are enabling technologies and methodologies which are very much significant to achieve agility (Haq and Boddu, 2015). In this section, we focus on various drivers and enablers of supply chain agility collected from literature.

Study of the agility enablers is primarily done by Gunasekaran (1998). He developed a conceptual diagram for supply chain agility to illustrate the enablers of agile manufacturing as shown in Figure 2.4. In order to achieve agility in supply chain, physically distributed firms need to integrate and manage these enablers effectively so that the system is able to adapt to changing market conditions. It can be seen from the proposed conceptual model that different enablers of agile manufacturing are overlapping each other. Therefore, all the enablers/tools should be integrated to achieve an effective integration and management of firms in a virtual enterprise.

Likewise Gunasekaran (1998), many researchers have recommended a set of enablers for different purposes. Few of them have derived the interrelationships between them.

Relationship between enablers aid in understanding the relative position and influences of the enablers on each other. Practically, this will allow management to efficiently utilise their resources to focus attention on the most significant enablers. Agarwal et al., (2007), Hasan et al., (2009), Pandey and Garg (2009), Mishra et al., (2012) and Sharma and Bhat (2014) have studied the interrelationship of different set of agility enablers using ISM.

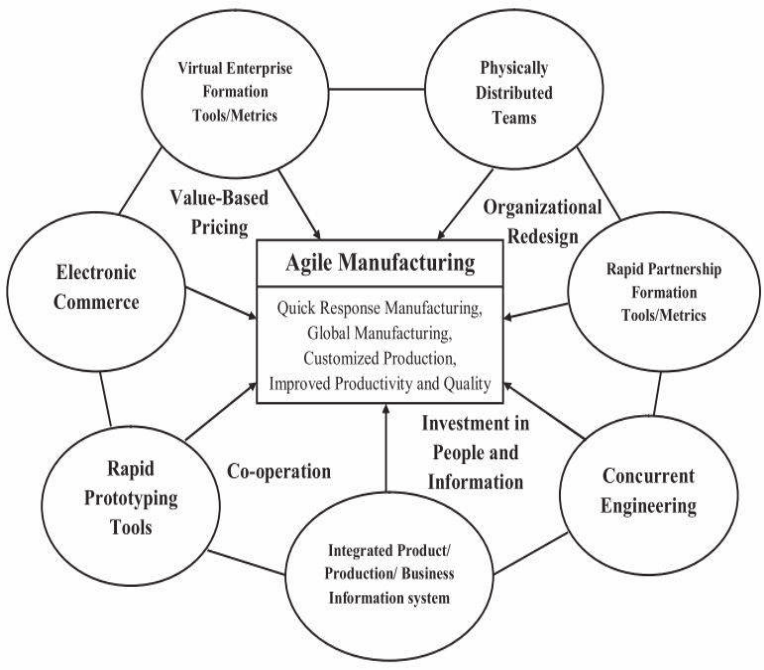


Figure 2.4: A conceptual diagram for agility model proposed by Gunasekaran (1998) to illustrate the concept and enablers of agile manufacturing

Agility enablers can be also used for the evaluation of agility in supply chain. Many of researchers are witness of that. Agility evaluation reveals the strategic agile position of an organisation in the competitive business environment (Vinodh et al., 2010). For the evaluation of agility, assessment models are developed by practitioners. These models are divided in to three stages. First stage consists of agility enablers, second stage consists of attributes of the enablers and third stage of the model consists of sub-attributes of the enablers. Agility enablers and their attributes were derived from the earlier researches reported in the literature. Lin et al., (2006b), Vinodh et al., (2010), Vinodh and Devadasan,

(2011), Vinodh and Prasanna (2011) and Vinodh et al., (2013) are the ones who contributed towards agility assessment using different set of enablers and their attributes.

In addition to these Saleeshya et al., (2012) and Haq and Boddu (2015) were the ones who developed the models for the improvement of agility in supply chain using the agility enablers. Saleeshya et al. (2012) have conducted a case study on textile industry that has a volatile market demand. Various enablers and determinants of agility were identified through literature review, field study and industry study. After that a multi level model was developed and the suitability of this model to improve the agility of supply chain was tested. Haq and Boddu (2015) used analytical hierarchy process to prioritise enablers for ASC in the context of Indian food processing industries. Understanding these priorities help food processing industries develop strategies to improve supply chain agility.

Apart from these works, agility enablers are also used for different purposes. Table 2.5 summarizes the enablers of agility and the sources from where to attain it for the different uses.

Table 2.5: Lists of agility enablers and their uses

| **Authors** | **Enablers of agility** | **Use of suggested enablers** |
|---|---|---|
| Gunasekaran (1998) | Virtual enterprise formation tools/metrics, physically distributed teams, rapid partnership formation tools/metrics, concurrent engineering, integrated product/ production/ business information system, rapid prototyping tools, electronic commerce. | Implementation of agility in supply chain |
| Yusuf et al., (1999) | Automation and price/cost consideration, widening customer choice and expectation, competing priorities, integration and proactivity, achieving manufacturing requirements in synergy | Present the genesis of the agile manufacturing concept |
| Van Hoek et al., 2001) | Customer sensitivity, virtual integration, process integration, network integration. | Assess supply chain agility |

| | | |
|---|---|---|
| Lin et al., (2006b) | Leverage people and information technology, Master change and uncertainty, Collaborative relationships | Agility evaluation |
| Agarwal et al., (2007) | Market sensitiveness, Delivery speed, Data accuracy, New product introduction, Centralized and collaborative planning, Process integration, Use of IT tools, Lead time reduction, Service level improvement, Cost minimization, Customer satisfaction, Quality improvement, Minimizing uncertainty, Trust development, Minimizing resistance to change | Derived interrelationships of the agility enablers |
| Vinodh and Prasanna (2011) | Virtual Enterprise, Collaborative relationship, Strategic Management, Information technology management, market sensitivity | Evaluation of agility in supply chain |
| Mishra et al., (2012) | Widening customer requirements, competition criteria, culture of rapid change, technological advancements, social factors, integration and proactivity, reduced lead time | Establishing the mutual relationships among the enablers |
| Saleeshya et al., (2012) | Strategy development and implementation, efficient organizational infrastructure, customer centred paradigm, workforce management, manufacturing planning, optimum technology utilization | Improvement of the agility of supply chain |
| Sharma and Bhat (2014) | Build-to-order, Market sensitivity, Flexibility, Adaptability, Collaborative relationships, Virtual integration, Network-based. | Establishing the mutual relationships among the enablers |
| Haq and Boddu (2015) | Strategic management, collaboration management, knowledge and information technology management, manufacturing management, customer and market sensitivity | Develop AHP based framework to improve agility |

### 2.7 Agility and tradeoffs

Introducing agility at various stages of supply chain makes it more complex, and this complexity sometimes goes against the agility. Implementing agility may affect a number of parameters in supply chains. Thus, it seems like agility is essential but the associated trade-offs must be thoroughly analysed before its implementation. The tradeoffs between

agility and various parameters are being presented here to provide an overview to the researchers and professionals looking for agility in their study or supply chains.

### 2.7.1 Agility and efficiency

Efficiency means efficient and effective use of all the resources in supply chain. Agility refers to the ability of a firm to manufacture and deliver a broad range of high quality products and services with short lead times and varying volumes to provide enhanced value to customers. Efficiency refers to the ability of a firm to manufacture and deliver same quality and range of product and service at low cost. Agility means changes in tactics and operations quickly in order to respond to altering environment conditions. When inflexion points emerge, uncertainty is enhanced and change is necessary for firms to remain competitive. However, since change is costly and achieving agility often involves sacrificing efficiency (Teece et al., 2016); one cannot assert that business firms should organize continuously for agility.

### 2.7.2 Agility and reliability

Increasing agility of supply chain tends to decrease reliability. A reliable system is one which is least prone to uncertainty. When agility is incorporated, basically a system is developed to counter uncertainties, so by mere definition they tend to oppose each other. Agility therefore should be incorporated without negotiating much with the reliability of the system. No such work is reported in literature and this could be possible research gap for researchers to carry on with their work.

### 2.7.3 Agility and uncertainty

Uncertainty has been a major topic for management research long before the term agility was introduced (Zhang, 2011). The agility in supply chains provides innovative products to customer with a high degree of market volatility and uncertainty in demand. James (2005)

defined agility as ability to respond to change and uncertainty in the business environment. Supply chain agility deal with many sources of uncertainty, such as customer demand, supply quality, lead-time, and information delay, etc. Prater et al., (2001) believe that by decreasing uncertainty a firm may decrease the potential harm to its operations and position in the market. They have used five case studies to show the techniques of better trade-off between uncertainty and supply chain agility by creating a link between the two called supply chain exposures.

### 2.8 Research gaps identified

As discussed earlier, agility is the fundamental characteristic of a supply chain needed for survival in markets which are volatile and difficult to predict. Therefore, agility across supply chain is essential for their survival in turbulent and volatile markets. From last decade supply chain agility has been a very fertile area for research among practitioners. After going through the literature, it has been identified that there is still a lot of scope for research in this area. Some potential research directions that evolved during the course of reviewing literature are as below.

- To make the supply chain agile, large numbers of variables play their role and hence enable the supply chain to be agile (Pandey and Garg, 2009). These variables are known as enablers of agile supply chain. Identification of ASC enablers is necessary for supply chain manager not only to understand the fundamental preconditions of supply chain agility, but also to provide a practical guide to successful evolution to a truly agile supply chain. By identifying these enablers, an organization can channelize its resources in the most effective manner in order to improve business performance. It is required to work with all ASC enablers but it is not essential to give same attention to all enablers. Hence it is quite important for supply chain manager to understand their relative

importance. Hence one of the research gap identified is identification of appropriate agility enablers and establishing their relationship.

- Another research agenda in agile manufacturing is the assessment of agility in the supply chain. It is necessary for supply chain manager to know where their supply chain agility stands. For this purpose evaluation of agility is important. Evaluation of agility is like an agility metric which is an important indicator for the performance measure of supply chain. Contemporary supply chain managers are in need to measure the agility level of supply chain periodically. Agility level would ensure the practicing managers to know about how much their supply chain agility is away from optimal agility level. If there will be a gap between their agility level and optimal agility level, then it is recommended to identify the barriers within the supply chain. With the help of identified barriers, managers can improve the weaker areas of the supply chain.
- Next and very important research agenda identified in this dissertation is the maximization of agility in supply chain. As discussed earlier, the existing literature on maximization of agility has failed to sufficiently address the relevant perspectives, which indicates that agility maximization is a golden opportunity for practitioners. With the help of this inspiration an attempt has been made to develop AHP-GP model to maximize the agility of supply chain by deploying the yearly input resources.

**2.9 Objectives of the thesis**

In this dissertation, some of these research gaps are addressed, based on which the objectives of the thesis are summarized as below.

- To develop interrelationship amongst agile supply chain enablers
- To evaluate agility in supply chains using fuzzy logic approach
- To allocate weights to agile supply chain enablers using AHP
- To maximize the agility in supply chain by deploying the yearly input resources