# Analysis of agile supply chain enablers for an Indian manufacturing organisation

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**Abstract:** The objective of present work is to categorise agile supply chain (ASC) enablers and examine its relative importance for better implementation of agility in perspective of the Indian manufacturing industry. This study deploys, analytic hierarchy process (AHP), a popular multi-criteria decision making (MCDM) tool as a solution methodology, such that the decision problem breaks into a hierarchy of different levels constituting goal, criteria and alternatives. The results show that there are three enablers namely virtual enterprises, customer satisfaction and adaptability are among the top priority enablers; enabler collaborative relationship is the moderate priority enabler and remaining three enablers i.e., use of information technology, market sensitivity and flexibility are the lowest priority enablers. To effectively implement agility in the supply chain, this study proposes that the manufacturing industries need to focus on the most important ASC enablers and also address the enablers with the least important at a later stage.

**Keywords:** agile manufacturing; agile supply chain; ASC; agile supply chain enablers; analytic hierarchy process; AHP; flexibility; customer satisfaction; adaptability.

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## 1 Introduction

Manufacturing organisations are under immense market pressure due to globalisation, shorter product life cycle, changing demand patterns and supply disruption due to various risks and uncertainties. A survey of some 350 supply chain executives from across the globe identified that supply chain volatility and uncertainty have permanently increased for the next few years (Supply Chain Digest, 2010). It is quite essential for manufacturing organisation to adapt to these environmental changes quickly in order to survive in the market. Agility is one of the significant basics for survival of the organisation in turbulent and dynamic business environment. Large global organisations need to be highly flexible and agile to counter and handle internal and external changes in their business environment. Agility in supply chains is a critical factor due to its competitive advantages for organisations as it helps to explore and exploit opportunities in fast-changing markets. In today's business scenarios companies face continuous and unpredictable changes due to the situations such as uncertainty, global competition, and complexity in a business environment. Companies must cope effectively with continuous and unexpected changes to become competitive (Cao and Dowlatshahi, 2005). Incorporating agility in the supply chain will be helpful to survive and prosper in a competitive environment of these significant changes by reacting quickly and effectively to changing markets, driven by customer-designed products and services (Cho et al., 1996).

The original concept of agility was introduced by a group of researchers at Iaccoca Institute, Lehigh University, in 1991 (Bottani, 2009). Since then agility is widely accepted term in the manufacturing industry as a new competitive concept (Zhang, 2011). Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace (Naylor et al., 1999). Agarwal et al. (2007) mentioned that agility is the fundamental characteristic of supply chain required for survival in turbulent and volatile markets. But the process by which organisations can achieve agility in their supply chain is an important concern in present dynamic business environment. Therefore, the supply chain managers must implement some technologies and methodologies in their supply chain to achieve agility significantly. These technologies and methodologies are called agile supply chain (ASC) enablers. Hence 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 ASC. It is required to work with all ASC enablers but not essential to give the same attention to all enablers. Now another important question is to identify the relative importance of ASC enablers. This can be achieved by prioritising the ASC enablers. A review of literature on ASC enablers indicated that much has been reported about ASC enablers and their implementation in different sectors but little has been explored on prioritising these enablers. Thus, there is a pressing need to identify the criteria for determining implementation priority of ASC enablers for its successful implementation in the context of Indian manufacturing industries.

In order to bridge this gap in a more meaningful way, the present study uses an analytic hierarchy process (AHP) approach to determine the relative importance of ASC enablers in the context of Indian manufacturing organisation. For this purpose, the present research aims at achieving the following objectives: to investigate and finalise the ASC enablers of Indian manufacturing organisation; and to prioritise the relative importance of these ASC enablers for implementation so that the selected case-organisation can evaluate its current practices towards supply chain agility and re-allocate reasonably its resources to improve its supply chain performance. This topic is very much important for making an organisation agile. To sustain competitiveness in global markets, organisations need to have an ASC. The seven enablers identified in this research would help to impart agility in supply chains of manufacturing units in India. A supply chain can be robust and profitable if these enablers are incorporated properly based on their relative importance.

The structure of the paper has been organised in the following sequence of the sections: Section 2 elaborates the literature on agility enablers as well as AHP. The proposed framework for prioritising the agility enablers is described in Section 3. Section 4 covers explanation of the solution methodology. In Section 5, a numerical example and analysis of the results are explained. Finally, the conclusion and scope of future research are presented in Section 6.

## 2 A summary of the related literature

A number of research papers from literature have been reviewed for the present work from the perspective of ASC enablers and AHP approach.

### *2.1 Literature review on ASC enablers*

Gunasekaran (1998) was the first researcher who defined agility enablers and provided seven comprehensive set of agile enablers. He developed a conceptual framework for the development of an agile manufacturing system. Yusuf et al. (1999) presented the agile manufacturing concept and examined the driving forces behind agility. They have identified five drivers of agility and reported the portfolio of competitive advantages that have lately emerged as a result of the changing requirements of manufacturing. Christopher (2000) suggested four agility enablers which are namely: customer sensitivity, virtual integration, process integration and network integration. He believed that the key to survival in volatile and unpredictable market demand is agility. He further added that in order to be a truly agile, a supply chain must possess a number of distinguishing characteristics. These characteristics can be referred as ASC enablers. Jackson and Johansson (2003) have investigated the concept of agility and its implications to different manufacturing industries. A proposal on how to make an ‘agility’ analysis from a production system perspective is presented and a case study has been chosen to test the analysis in practice.

Agarwal et al. (2007), Hasan et al. (2009), Pandey and Garg (2009), Mishra et al. (2012), Sharma and Bhat (2014) and Patel et al. (2018) have identified a number of agility enablers and established interrelationships between them using similar approach of interpretive structural modelling (ISM). Lin et al. (2006), Vinodh and Devadasan (2011), Vinodh and Prasanna (2011), Vinodh et al. (2013) and Patel et al. (2017) have used agility enablers with a purpose of agility assessment of the supply chain. They have identified ASC enablers along with their criteria and attributes after that they have calculated the agility level of an organisation using fuzzy logic approach. Bustelo et al. (2007) developed systematic approach to analyse the agile manufacturing, considering various agility enablers in an integrated way and related them not only to environmental characteristics but also to the business performance. Bottani (2009) developed an approach to identify the most appropriate enablers to be implemented by companies starting from competitive characteristics of the related market. This is achieved by linking competitive bases, agile attributes and agile enablers. This approach is based on the quality function deployment methodology, and particularly of the house of quality.

Faisal (2011) prioritised agility variables for cold supply chains. He proposed a fuzzy-AHP-based framework to prioritise agility variables in supply chains. Experts' opinion was undertaken for cold supply chains to formulate a hierarchical structure of agility in supply chains. Saleeshya et al. (2012) developed a model by identifying various enabling factors with a view to improve the agility of textile supply chain. Enablers are identified through a case study, field study, discussions with industrial experts and consultants, and detailed literature review. Two methodologies such as AHP and ISM were used for analysis of the agile enablers. Samantra et al. (2013) have developed an approach, which is based on generalised trapezoidal fuzzy set for agility appraisal in the supply chain. The proposed framework is divided into three levels namely agile providers, agile criteria, and agile attributes which are interconnected in a logical manner, and the degree of effective interaction enhances supply chain agility. The proposed procedure was efficiently applied to a large-scale automobile manufacturing company in India. Dubey et al. (2014) have attempted to explain supply chain agility and supply chain resilience using oscillation physics theory and further, they tested the theoretical concept empirically using a psychometric tool. A finding of their study is that supply chain agility and supply chain resilience are important determinants of humanitarian supply chain performance. A conceptual model is proposed by Mishra et al. (2014) to achieve a firm's overall agility. They have exhibited 41 different agile entities which are categorised into 13 impact areas. Model is examined based on a questionnaire, followed by statistical analysis. The concept and the application of factor analysis (FA) is used to achieve effective dimensions on organisational supply chain agility. This is a tool for decision makers (DMs) and company managers to assist them in achieving their enhanced agility level. An AHP-based framework is proposed by Haq and Boddu (2015) to improve agility of food processing industries. They have identified 32 agile enablers based on literature review and experts' opinion. Enablers are grouped into five categories and prioritised using AHP. 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. Brusset (2016) has developed a conceptual framework to study supply chain agility using the dynamic capabilities approach within the resource-based-view of the firm, positioning himself from the vantage point of the supply chain manager. He surveyed 171 French supply chain managers and analysed the supply chain managers' action, decision, practices, and how their routine set up contribute to the agility of the supply chain for the firm they belongs. He employed the FA and a structural equation model to analyse the responses. Finally, he concluded that external and internal managerial processes enhance agility. Sangari et al. (2016) contributed to the development of a comprehensive taxonomy of the factors that are critical to have a truly ASC. They have categorised 12 critical factors for achieving supply chain agility and validated through a quantitative survey of supply chain experts from the automotive industry. From the findings, an integrative framework is proposed as a reference for the development of supply chain agility.

### *2.2 Literature review on analytical hierarchy process*

AHP is introduced by Saaty in 1980 since then it is used worldwide in variety of fields like business, healthcare, industry and education. It is extensively accepted among the researchers as multi-criteria decision making (MCDM) tool for ranking and weighting alternatives. Several authors have reported the application of AHP such as selection of supplier, assess supply chain risks, evaluation of retail service quality, prioritisation of barriers to total quality management, selection of anti cancer drugs, selection of material for a given engineering application and so on. Few of them are explained as follows.

Pun and Hui (2001) studied the critical decision criteria, sub-criteria and benefits of ISO 14001 Environmental Management Systems (EMS) and proposed an AHP decision model of EMS adoption. The proposed AHP decision model helps to assess the relevant criteria critically and logically, and assists the decision-making process of ISO 14001 EMS adoption. Based on the findings of this empirical study, they concluded that the proposed AHP decision model provides an effective means to help managers in determining the priorities among decision criteria and benefits and assess the effectiveness of EMS adoption in their organisations. Dey et al. (2006) have applied AHP in healthcare service. They developed a performance measurement model to measure the performance of ICU's of three hospitals by conducting focus group discussions between anaesthesiologists, senior nurses, staff nurses from all three hospitals who were involved in the day-to-day management of the ICUs. Proposed model have three selection criteria (i.e., structure of the unit, process of care and outcome of patients) along with their associated sub-criteria. The alternatives of the problems are Barbadian ICU, Trinidadian ICU and Indian ICU. The result revealed that Barbadian ICU performed much better (44%) than both the Trinidadian ICU (33%) and the Indian ICU (23%). The AHP model was proposed by Levary (2008) to evaluate and rank of the potential suppliers. The model considered four criteria (i.e., Supplier reliability, Country risk, Reliability of the transportation and Reliability of the supplier's suppliers) to rank three supplier alternatives. A realistic case study was presented in which a manufacturer evaluates and ranks its current foreign supplier (Chinese supplier) against two other potential foreign suppliers (Brazilian supplier and Ukrainian supplier) based on four criteria mentioned earlier.

Singh (2012) applied AHP to justify the application of coordinated SC in small and medium enterprises (SMEs) on basis of major benefits derived from literature review. From analysis, it was observed that out of seven major benefits of coordinated SC, inventory reduction revealed the highest global desirability index. Inventory reduction was followed by cost reduction, lead time reduction, agility in SC, delivery on time, service reliability and accurate forecasting of data. Govindan et al. (2014) focused on identifying barriers to the implementation of a green supply chain management (green SCM) based on procurement effectiveness. A total of 47 barriers were identified, both through detailed literature and discussion with industrial experts and through a questionnaire-based survey from various industrial sectors. Essential barriers/priorities were identified through recourse to AHP. Finally, a sensitivity analysis was carried out to investigate the priority ranking stability. Misra and Panda (2017) investigated the activities of environmental consciousness from socio-psychographic perspectives and hence evaluated its effect on brand equity through intervening elements of environmental attributes (EAt). This study concentrates on three destinations of India and proposed to investigate the activities of environmental consciousness taking into account social-psychographic data and evaluate its effect on brand equity through EAt by using an analytic hierarchy process (AHP). It further prioritised the effect of the company's environmental communication, environmental performance and environmental positioning in upgrading the brand equity. Acharya et al. (2018) categorised industrial automation (AI) factors and examined its relative importance for better implementation in manufacturing industries. In all, 13 IA factors were identified and further divided into three factor categories. Thereafter, their prioritisation was done using AHP approach to assign the relative importance of these 13 factors affecting the AI in manufacturing industries.

## 3 Problem description

The contemporary manufacturing organisations face unexpected changes due to business situations such as global competition, shorter product life cycles and dynamic changes of demand patterns. These unexpected changes are an inhibitor to firms business and to counter it supply chains must have ability to respond quickly to the changing business environments. Agility is the fundamental characteristic of a supply chain needed for survival in unexpected changes. Agility further helps in delivering the right amount of product, at the right time to the consumer, which is the main objective of any supply chain (Agarwal et al., 2007). To make the supply chain agile, large numbers of variables play a vital role and hence enable the supply chain to be agile. These variables are known as enablers of ASC.

In this study ASC enablers are identified and prioritised using AHP as a solution methodology. It is important for the Indian manufacturing organisation to investigate and categorise the ASC enablers and prioritise them with the aim of making the supply chain more agile in nature. The framework to prioritise ASC enablers is shown in Figure 1. According to Figure 1 first step is to identify ASC enablers of the supply chain. Identification of agility enablers begins with scanning of the literature. Literature was reviewed from the year 1995 to 2017 using the keywords such as agile manufacturing, agility, ASC enablers, agility index, etc. In order to collect the research papers for the review, a rigorous search was carried out using the database of reputed publishers like Emerald, Springer, Science direct, Elsevier, Taylor and Francis, Inderscience. Only journal papers were included in the review. Table 1 shows summary of literature review of ASC enablers. After literature survey discussion with experts from case-organisation and experts from academia were considered in the present study in order to finalise ASC enablers. From Table 1, it can be observed that adaptability is considered as ASC enabler even though it was identified in only one research paper (Sharma and Bhat, 2014). According to experts, adaptability positively affects the supply chain agility of the case-organisation. Apart from this several scholars have also acknowledged the importance of adaptability for agility of supply chain (Lee, 2004; Takii, 2007; Tuominen et al., 2004). Hence, adaptability was also considered in the list of ASC enablers.

**Figure 1** Framework for prioritising agility enablers

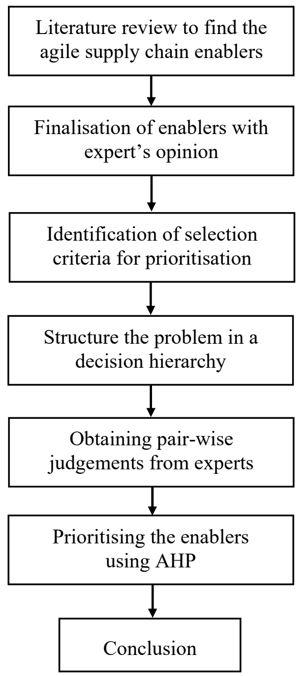



**Table 1** ASC enablers from the literature

| *ASC enablers* | *Source* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Gunasekaran (1999)* | *Christopher (2000)* | *Dowlatshahi and Cao (2006)* | *Faisal et al. ( 2006)* | *Agarwal et al. (2007)* | *Gunasekaran et al. (2008)* | *Swafford et al. (2008)* | *Hasan et al. (2009)* | *Pandey and Garg (2009)* | *Vinodh and Prasanna (2011)* | *Vinodh et al. (2013)* | *Sharma and Bhat (2014)* |
| Virtual enterprises | ✓ | | ✓ | | | ✓ | | ✓ | | ✓ | ✓ | |
| Collaborative relationship | | | | ✓ | | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| Use of IT | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Market sensitivity | | ✓ | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ |
| Customer satisfaction | | | | | ✓ | | | | ✓ | | | |
| Adaptability | | | | | | | | | | | | ✓ |
| Flexibility | | | | | | | ✓ | | | | | ✓ |

After thorough discussion, seven key enablers for making supply chain agile were finalised. These agility enablers are virtual enterprises (VE), collaborative relationship (CR), use of information technology (IT), market sensitivity (MS), customer satisfaction (CS), adaptability (AD) and flexibility (FL). A brief description of the seven identified agility enablers is as follows:

### *3.1 Virtual enterprises*

VE is a temporary alliance of enterprises that come together to share skills or core competencies and resources in order to better respond to business opportunities (Camarinha-Matos and Afsarmanesh, 1999). A single organisation is often not able to develop sufficient internal capabilities to respond effectively within a short period of time (Gunasekaran, 1998). Hence, the company uses virtual enterprise to form temporary alliances in order to make a specific product for a specific period of time and then, dissolve these alliances when projects' objectives have been achieved. The main objective of a VE is to allow a number of organisations to rapidly develop a common working environment (Martinez et al., 2001).

### *3.2 Collaborative relationship*

Each partner of supply chain has to establish CR in order to survive under uncertain and dynamic environment. A CR is a closed and coordinated relationship of organisations with their major business partners such as suppliers, manufacturers and distributors (Sharma and Bhat, 2014). Firms build CR s with their supply chain partners to achieve efficiencies, flexibility, and sustainable competitive advantage (Nyaga et al., 2010). All participating members make all necessary arrangements of collaborative practices, play according to rules, struggle to achieve the leading SCs benchmarks, and follow all ethical principles to make things work well (Mehrjerdi, 2009).

### *3.3 Use of IT*

Use of IT involves the use of various software and tools (like internet, extranet, electronic data interchange (EDI), material requirement planning, manufacturing resource planning and so on) which results in the quick and fast flow of information. The speedy flow of information makes the supply chain more agile (Pandey and Garg, 2009). There are many advantages of using IT tools. EDI and the internet have enabled partners in the supply chain to act upon the same data (Agarwal et al., 2006), enterprise resource planning (ERP) helps to achieve time reductions and quality improvement in product design and development (Dowlatshahi and Cao, 2006). Other IT tools such as flexible simulation software system and rapid prototyping software can be also employed to improve agility in supply chain (Gunasekaran, 1999).

### *3.4 Market sensitivity*

The supply chains of the today's business environments are under tremendous pressure due to uncertainties associated with demand. To overcome this problem supply chain must be market sensitive. Market sensitive means that the supply chain must be capable of reading and responding to real demand (Christopher, 2000). The market sensitiveness of a supply chain is affected by level of collaboration among its trading partners, and its ability of using IT tools (Agarwal et al., 2006). A closed and coordinated relationship of manufacturer with the customer helps to get data on actual customer requirements which reduce degree of variability in demand.

### *3.5 Customer satisfaction*

CS means the customer's reaction to the value received from the purchase or utilisation of the offering (Agarwal et al., 2007). The whole exercise of the supply chain aims to satisfy the end customer. Hence, supply chain strategy should focus on CS. High level of CS gives high level of profitable opportunity because a satisfied customer is more liable to become a repeated buyer and spread positive word-of-mouth which might create new customer for a business (Yu et. al., 2005). Thus, for improving agility, supply chain metrics must be linked to CS (Haq and Boddu, 2015).

### *3.6 Adaptability*

Adaptability is the firm's ability to correctly predict and therefore appropriately adapt to an unexpected change in the environment (Takii, 2007). It adjusts supply chain's design to meet structural shifts in markets; modify supply network to strategies, products and technologies (Lee, 2004). To better cope with unexpected changes in the environment, supply chain has to be adaptive at supplier level, at production unit as well as at distributor level. Supply chain manager must always try to find out unexpected changes before they occur. It can be done by capturing the latest data, filtering out noise and tracking key patterns (Lee, 2004).

### *3.7 Flexibility*

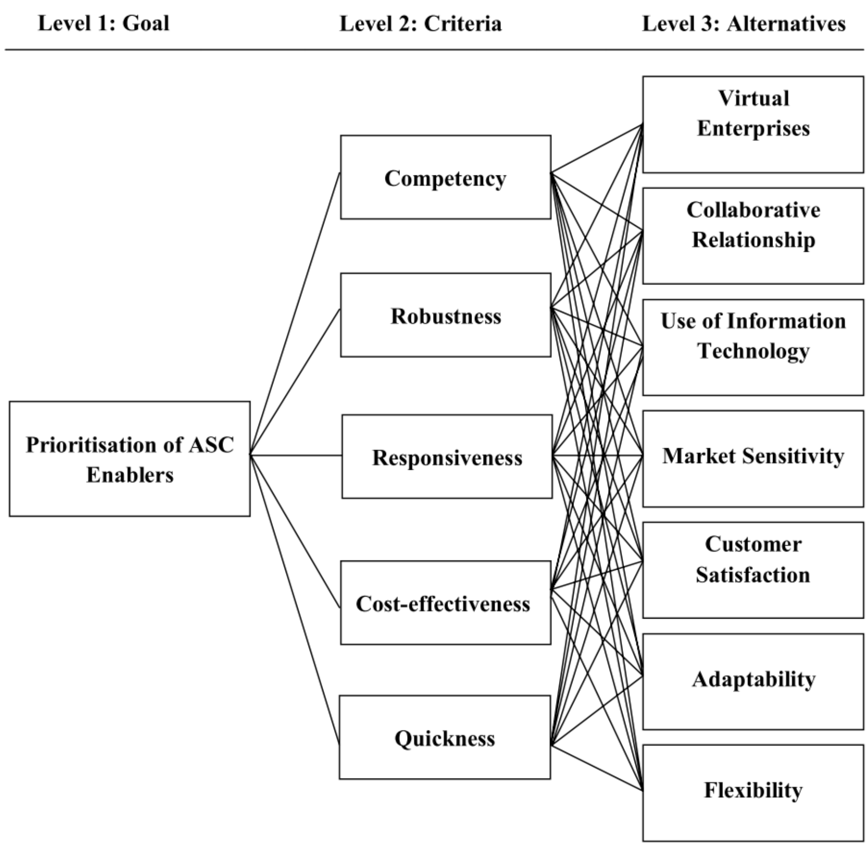
Flexibility is the key characteristic of an agile organisation (Christopher and Towill, 2001). A flexible supply chain is one which can rapidly respond to any change that might arise at any element right from supplier to the end user in the supply chain (Tiwari et al., 2013, 2015). Flexibility can be classified in different dimensions e.g., supply chain flexibility, organisation flexibility and operational flexibility. Supply chain flexibility is the ability to re-configure the supply chain (Stevenson and Spring, 2007). Organisation flexibility means ability to cope with unexpected changes at plant level and firm level. Operational flexibility is associated with resource flexibility and shop floor flexibility. It refers to the ability to manage machine, labour, operation, process, routing and material handling.

After identifying and finalising ASC enablers, next step is to decide the selection criteria for prioritising agility enablers. To judge the alternatives, decision maker has to understand and know on what basis decision has been taken. This basis is called as selection criteria. Selection process is influenced by a variety of criteria. The criteria can be tangible (i.e., objective) as well as non-tangible (i.e., subjective) (Rao, 2007). For the present problem, the selection criteria such as competency, robustness, responsiveness, cost-effectiveness and quickness are selected which are shown in Table 2.

**Table 2** Selection criteria of ASC enablers

| *Selection criteria* | *Definition* | *References* |
|---|---|---|
| Competency | Capability of effective and efficient accessibility to the organisation's targets goals. | Yaghoubi and Kord (2011), Zhang (2011), Sharifi and Zhang (1999) and Tseng and Lin (2011) |
| Robustness | Ability to withstand variations and disturbances and direct it to take advantage of these fluctuations to maximise the profit. | Yauch (2011), Naylor et al. (1999) and Tseng and Lin (2011) |
| Responsiveness | Ability to identify changes and respond to them quickly. | Carvalho et al. (2012), Yaghoubi and Kord (2011), Zhang (2011) and Tseng and Lin (2011) |
| Cost-effectiveness | Ability to respond to unexpected changes in a cost-effectiveness manner. | Tseng and Lin (2011) and Ganguly et al. (2009) |
| Quickness | Capability to execute an operation in shortest time | Yaghoubi and Kord (2011) and Sharifi and Zhang (1999) |

**Figure 2** Decision hierarchy for the prioritisation of agility enablers



Identification of alternatives and selection criteria are followed by structuring the problem in a decision hierarchy of different levels constituting goal, criteria and alternatives. Decision hierarchy of the problem is shown in Figure 2. The first level of hierarchy shows the goal of the problem which is to prioritise ASC enablers. At the second level, there are five criteria which contribute to achieve the overall goal. Finally, the third level lists the suggested seven ASC enablers as alternatives.

## 4 Solution methodology

The present work employed the AHP technique as multi-criteria decision-making (MCDM) tool to evaluate the priority of ASC enablers for Indian manufacturing organisation. AHP is a powerful technique for solving complicated and unstructured problems that may have interactions and correlations among different objectives and goals (Acharya et al., 2018). In this technique a complex, multi-criteria problem is simplified into three levels of hierarchy with the first level as the goal, while the second level is the criteria and the third level offers alternatives, forming a hierarchy structure. AHP is one of the most popular and widely accepted decision making technique and is extensively applied in different areas with different applications. AHP is still a good choice as MCDM tools, although, more than three decades old decision making method, due to its intuitiveness, easy applicability, well validated consistency, broad set of application and so on.

In order to investigate the relative priorities of the ASC enablers for Indian manufacturing organisation, AHP methodology is used in the present work. The step by step explanation of AHP is as follows:

Step 1 Define the objective or goal.

First step of the AHP methodology is to determine the objective of the problem, selection criteria, and alternatives.

Step 2 Construct a hierarchy framework for analysis.

After determining the objective, criteria and alternative, structure the problem into a hierarchy. Hierarchy of the problem consists of goal at the first level, the criteria and sub-criteria (if any) at second level and the alternatives at the third level.

Step 3 Collection of data for pair-wise comparisons of criteria and alternatives.

This step is concerned with the preparation of questionnaire and collection of empirical information through the combined judgments of the experts from case-organisation and academia. After collecting empirical information, construct a pair-wise comparison matrix of criteria and pair-wise comparison matrix of alternatives with respect to each criterion.

Step 4 Calculating priority weights of criteria.

Once the pair-wise comparisons of criteria and alternatives are obtained next step is to calculate the priority weights of criteria. Priority weights of criteria are obtained by normalising the pair-wise comparison matrix of criteria.

Step 5 Calculating priority weights of alternative with respect to each criterion.

This step involves calculation of priority weights of each alternative with respect to each criterion.

Step 6: Check the consistency of pair-wise judgements.

This step examines whether the pair-wise comparison are consistent or not. It might be possible that, through the pair-wise comparisons, experts may be inconsistent in their judgments. The AHP technique has capability to check the consistency of pair-wise comparisons.

Step 7 Computation of the overall weights of alternatives.

Once the priority weights of alternatives with respect to each criterion are obtained, they are aggregated to find overall weights of the alternatives by multiplying the priority weights of decision alternatives to priority weights of selection criteria and summing over all criteria.

Step 8 Analyse the findings.

Finally prioritisations of alternatives are obtained. Alternative with highest priority weights are considered as more desirable followed by next higher priority weights and so on.

## 5 A numerical example

To prioritise ASC enablers for Indian manufacturing organisation, the data for pair-wise comparisons of criteria with respect to goal and pair-wise comparisons of alternatives with respect to each of the criterion is required. The pair-wise comparison is established using nine-point scale as suggested by Saaty (1980) (Table 3). This scale indicates how important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. With use of Table 3, the pair-wise comparison matrix for criteria and pair-wise comparison matrix of alternatives with respect to each criterion are constructed.

**Table 3** Scale of relative preference for pair wise selection

| *Scale* | *Definition* |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance of one over another |
| 5 | Strong importance of one over another |
| 7 | Very strong importance of one over another |
| 9 | Extreme importance of one over another |
| 2, 4, 6, 8 | Intermediate value between two adjacent judgments |

### *5.1 Data collection*

The AHP is often used in group settings where group members either engage in discussion to achieve a consensus or express their own preferences (Forman and

Peniwati, 1998). The group discussion process has several advantages over aggregation of individual ratings. For the prioritisation of ASC enablers, pair-wise comparison of ranking criteria and pair-wise comparison of enablers with respect to each of the criterion is required. Response from single expert for pair-wise comparison contains a total of six matrices. As the number of expert increases, total number of matrices also increases in the multiple of six. Hence, individual response from multiple experts makes the problem complex and lengthy. Erkut and Moran (1991) believed that group discussion process facilitates a common understanding of the meaning and significance of each criterion. This commonality of understanding cannot be achieved through aggregating the inputs of individual evaluations. The group is often able to clarify misunderstandings and differences in interpretation of the data so that there is a more uniform understanding of the facts. In addition, a group process utilises the dynamics of powerful influence within the decision-making.

Therefore, for the present problem group discussion process was preferred to reach consensus for the pair-wise comparison of criteria and alternatives rather than individual preferences by experts. In group discussion process, the groups establish a single set of weights for the decision criteria and then rates the decision alternatives. For the group discussion, various management techniques (such as brain storming, nominal group technique, etc.) can be used to collect the data. In order to collect the data for pair-wise comparison, the first author approach to the respondents of case-organisation. Before the commencement of comparison, the objective of the survey was briefly introduced to the targeted respondents to ensure full understanding of the survey questionnaire, overall goals and objectives of the research and how data would be used. There were four experts from the case-organisation and two experts from academia, who gave their precious time for brain storming session. Each expert with more than 20 years of experience in the supply chain domain was selected for this procedure. They were asked to give pair-wise comparison weight with reference to the Saaty nine-point scale values as shown in Table 3. At the end of brain storming session pair-wise comparisons of criteria (Table 4) and pair-wise comparisons of enablers with respect to each criterion (Table 5 to Table 9) were obtained. Pair-wise comparison data indicates how important one element compared to another element. For example, in the case of pair-wise comparison of criteria (Table 4), if experts decide that ‘competency’ are moderately important than ‘Responsiveness’, then based on scale of preferences between two elements, a number ‘3’ was assigned in Table 4. Hence, reciprocally the ‘responsiveness’ is ‘1/3’ times less important than the ‘competency’.

**Table 4** Pair-wise comparison of ranking criteria (see online version for colours)

| | *A* | *B* | *C* | *D* | *E* |
|---|---|---|---|---|---|
| Competency (A) | 1 | 1/3 | 3 | 5 | 5 |
| Robustness (B) | 3 | 1 | 5 | 5 | 5 |
| Responsiveness (C) | 1/3 | 1/5 | 1 | 1 | 1 |
| Cost effectiveness (D) | 1/5 | 1/5 | 1 | 1 | 1 |
| Quickness (E) | 1/5 | 1/5 | 1 | 1 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

**Table 5** Pair-wise comparison of enablers with respect to competency (A) (see online version for colours)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* |
|---|---|---|---|---|---|---|---|
| VE | 1 | 3 | 7 | 7 | 3 | 3 | 3 |
| CR | 1/3 | 1 | 5 | 5 | 1 | 3 | 3 |
| IT | 1/7 | 1/5 | 1 | 1 | 1/5 | 1/3 | 1/3 |
| MS | 1/7 | 1/5 | 1 | 1 | 1/5 | 1/3 | 1/3 |
| CS | 1/3 | 1 | 5 | 5 | 1 | 3 | 3 |
| AD | 1/3 | 1/3 | 3 | 3 | 1/3 | 1 | 1 |
| FL | 1/3 | 1/3 | 3 | 3 | 1/3 | 1 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

**Table 6** Pair-wise comparison of enablers with respect to robustness (B) (see online version for colours)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* |
|---|---|---|---|---|---|---|---|
| VE | 1 | 1 | 3 | 1 | 1/5 | 1/3 | 3 |
| CR | 1 | 1 | 3 | 1 | 1/3 | 1/3 | 1 |
| IT | 1/3 | 1/3 | 1 | 1/3 | 1/3 | 1/5 | 3 |
| MS | 1 | 1 | 3 | 1 | 1/3 | 1/3 | 3 |
| CS | 5 | 3 | 3 | 3 | 1 | 1 | 5 |
| AD | 3 | 3 | 5 | 3 | 1 | 1 | 5 |
| FL | 1/3 | 1 | 1/3 | 1/3 | 1/5 | 1/5 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

**Table 7** Pair-wise comparison of enablers with respect to responsiveness (C) (see online version for colours)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* |
|---|---|---|---|---|---|---|---|
| VE | 1 | 5 | 3 | 5 | 5 | 3 | 3 |
| CR | 1/5 | 1 | 1/3 | 1 | 3 | 1/3 | 1/3 |
| IT | 1/3 | 3 | 1 | 3 | 3 | 3 | 3 |
| MS | 1/5 | 1 | 1/3 | 1 | 3 | 1/3 | 1/3 |
| CS | 1/5 | 1/3 | 1/3 | 1/3 | 1 | 1/3 | 1/3 |
| AD | 1/3 | 3 | 1/3 | 3 | 3 | 1 | 1 |
| FL | 1/3 | 3 | 1/3 | 3 | 3 | 1 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

**Table 8** Pair-wise comparison of enablers with respect to cost-effectiveness (D) (see online version for colours)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* |
|---|---|---|---|---|---|---|---|
| VE | 1 | 1 | 1/3 | 5 | 3 | 3 | 5 |
| CR | 1 | 1 | 1/3 | 3 | 1/3 | 5 | 5 |
| IT | 3 | 3 | 1 | 5 | 1 | 5 | 5 |
| MS | 1/5 | 1/3 | 1/5 | 1 | 1/3 | 1 | 1 |
| CS | 1/3 | 3 | 1 | 3 | 1 | 3 | 3 |
| AD | 1/3 | 1/5 | 1/5 | 1 | 1/3 | 1 | 3 |
| FL | 1/5 | 1/5 | 1/5 | 1 | 1/3 | 1/3 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

**Table 9** Pair-wise comparison of enablers with respect to quickness (E) (see online version for colours)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* |
|---|---|---|---|---|---|---|---|
| VE | 1 | 3 | 5 | 3 | 5 | 5 | 3 |
| CR | 1/3 | 1 | 3 | 1 | 3 | 3 | 3 |
| IT | 1/5 | 1/3 | 1 | 1/3 | 1 | 1 | 3 |
| MS | 1/3 | 1 | 3 | 1 | 3 | 3 | 3 |
| CS | 1/5 | 1/3 | 1 | 1/3 | 1 | 1 | 3 |
| AD | 1/5 | 1/3 | 1 | 1/3 | 1 | 1 | 1 |
| FL | 1/3 | 1/3 | 1/3 | 1/3 | 1/3 | 1 | 1 |

Note: Coloured cells indicate that diagonal entries in all pair-wise comparison matrices are 1.

## 5.2 *Calculating priority weights of criteria*

After obtaining the pair-wise judgements, next step was to calculate the priority weights of criteria. In order to calculate priority weights of criteria, the pair-wise comparison matrix of criteria was normalised by dividing the elements of each column by the sum of the corresponding column. Thereafter, the average of each row was calculated to obtain the corresponding priority vector or priority weight. Table 10 shows the normalised matrix of paired comparison and calculation of priority weights of criteria. From Table 10, one can predict that highest priority which is enjoyed by robustness (0.475) whereas cost-effectiveness (0.078) and quickness (0.078), has the lowest priority.

**Table 10** Normalised matrix and calculation of priority weights of selection criteria

| | *A* | *B* | *C* | *D* | *E* | *∑ of row* | *Average = ∑ / 5* |
|---|---|---|---|---|---|---|---|
| A | 0.212 | 0.173 | 0.273 | 0.385 | 0.385 | 1.428 | 0.285 |
| B | 0.634 | 0.518 | 0.454 | 0.384 | 0.384 | 2.374 | 0.475 |
| C | 0.070 | 0.103 | 0.091 | 0.077 | 0.077 | 0.418 | 0.084 |
| D | 0.042 | 0.103 | 0.091 | 0.077 | 0.077 | 0.390 | 0.078 |
| E | 0.042 | 0.103 | 0.091 | 0.077 | 0.077 | 0.390 | 0.078 |

### 5.3 *Calculating priority weights of ASC enablers with respect to each criterion*

In this step priority weight of ASC enablers with respect to each criterion was calculated using similar kind of approach as explained for criteria in previous section. Each pair-wise comparison matrix (Table 5 to Table 9) of ASC enablers was normalised by dividing the elements of each column by the sum of the corresponding column. Then, the average of each row was obtained for corresponding priority vector or priority weight. Table 11–15 shows normalised matrix of paired comparison and calculation of priority weights of enablers with respect to each criterion.

**Table 11** Normalised matrix and calculation of priority weights of enablers (w.r.t. competency)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* | *∑ of row* | *Average = ∑ / 7* |
|---|---|---|---|---|---|---|---|---|---|
| VE | 0.382 | 0.494 | 0.280 | 0.280 | 0.494 | 0.257 | 0.257 | 2.444 | 0.349 |
| CR | 0.127 | 0.165 | 0.200 | 0.200 | 0.165 | 0.257 | 0.257 | 1.371 | 0.196 |
| IT | 0.055 | 0.033 | 0.040 | 0.040 | 0.033 | 0.029 | 0.029 | 0.259 | 0.037 |
| MS | 0.055 | 0.033 | 0.040 | 0.040 | 0.033 | 0.029 | 0.029 | 0.259 | 0.037 |
| CS | 0.127 | 0.165 | 0.200 | 0.200 | 0.165 | 0.257 | 0.257 | 1.371 | 0.196 |
| AD | 0.127 | 0.055 | 0.120 | 0.120 | 0.055 | 0.086 | 0.086 | 0.649 | 0.093 |
| FL | 0.127 | 0.055 | 0.120 | 0.120 | 0.055 | 0.085 | 0.085 | 0.649 | 0.092 |

**Table 12** Normalised matrix and calculation of priority weights of enablers (w.r.t. robustness)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* | *∑ of row* | *Average = ∑ / 7* |
|---|---|---|---|---|---|---|---|---|---|
| VE | 0.086 | 0.097 | 0.164 | 0.103 | 0.059 | 0.098 | 0.143 | 0.749 | 0.107 |
| CR | 0.086 | 0.097 | 0.164 | 0.103 | 0.098 | 0.098 | 0.048 | 0.693 | 0.099 |
| IT | 0.029 | 0.032 | 0.054 | 0.035 | 0.098 | 0.059 | 0.143 | 0.449 | 0.064 |
| MS | 0.086 | 0.097 | 0.164 | 0.103 | 0.098 | 0.098 | 0.143 | 0.788 | 0.113 |
| CS | 0.426 | 0.290 | 0.164 | 0.311 | 0.294 | 0.294 | 0.238 | 2.019 | 0.288 |
| AD | 0.258 | 0.290 | 0.272 | 0.311 | 0.294 | 0.294 | 0.238 | 1.957 | 0.280 |
| FL | 0.029 | 0.097 | 0.018 | 0.034 | 0.059 | 0.059 | 0.047 | 0.343 | 0.049 |

**Table 13** Normalised matrix and calculation of priority weights of enablers (w.r.t. responsiveness)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* | *∑ of row* | *Average = ∑ / 7* |
|---|---|---|---|---|---|---|---|---|---|
| VE | 0.385 | 0.306 | 0.529 | 0.306 | 0.238 | 0.333 | 0.333 | 2.430 | 0.347 |
| CR | 0.077 | 0.061 | 0.059 | 0.061 | 0.143 | 0.037 | 0.037 | 0.475 | 0.068 |
| IT | 0.128 | 0.184 | 0.176 | 0.184 | 0.143 | 0.333 | 0.333 | 1.481 | 0.211 |
| MS | 0.077 | 0.061 | 0.059 | 0.061 | 0.143 | 0.037 | 0.037 | 0.475 | 0.068 |
| CS | 0.077 | 0.020 | 0.059 | 0.020 | 0.047 | 0.037 | 0.037 | 0.297 | 0.042 |
| AD | 0.128 | 0.184 | 0.059 | 0.184 | 0.143 | 0.111 | 0.111 | 0.922 | 0.132 |
| FL | 0.128 | 0.184 | 0.059 | 0.184 | 0.143 | 0.112 | 0.112 | 0.922 | 0.132 |

**Table 14** Normalised matrix and calculation of priority weights of enablers (w.r.t. cost-effectiveness)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* | *∑ of row* | *Average = ∑ / 7* |
|---|---|---|---|---|---|---|---|---|---|
| VE | 0.165 | 0.114 | 0.103 | 0.262 | 0.474 | 0.164 | 0.218 | 1.499 | 0.214 |
| CR | 0.165 | 0.114 | 0.102 | 0.158 | 0.053 | 0.273 | 0.218 | 1.081 | 0.154 |
| IT | 0.494 | 0.344 | 0.306 | 0.263 | 0.157 | 0.273 | 0.218 | 2.055 | 0.294 |
| MS | 0.033 | 0.038 | 0.061 | 0.053 | 0.053 | 0.054 | 0.043 | 0.335 | 0.048 |
| CS | 0.055 | 0.344 | 0.306 | 0.158 | 0.157 | 0.164 | 0.130 | 1.314 | 0.188 |
| AD | 0.055 | 0.023 | 0.061 | 0.053 | 0.053 | 0.054 | 0.130 | 0.429 | 0.061 |
| FL | 0.033 | 0.023 | 0.061 | 0.053 | 0.053 | 0.018 | 0.043 | 0.283 | 0.041 |

**Table 15** Normalised matrix and calculation of priority weights of enablers (w.r.t. quickness)

| | *VE* | *CR* | *IT* | *MS* | *CS* | *AD* | *FL* | *∑ of row* | *Average = ∑ / 7* |
|---|---|---|---|---|---|---|---|---|---|
| VE | 0.385 | 0.474 | 0.349 | 0.474 | 0.348 | 0.332 | 0.176 | 2.540 | 0.363 |
| CR | 0.128 | 0.157 | 0.209 | 0.157 | 0.210 | 0.200 | 0.176 | 1.239 | 0.177 |
| IT | 0.077 | 0.053 | 0.070 | 0.053 | 0.070 | 0.067 | 0.176 | 0.565 | 0.081 |
| MS | 0.128 | 0.157 | 0.209 | 0.157 | 0.209 | 0.200 | 0.176 | 1.239 | 0.177 |
| CS | 0.077 | 0.053 | 0.070 | 0.053 | 0.070 | 0.067 | 0.176 | 0.565 | 0.081 |
| AD | 0.077 | 0.053 | 0.070 | 0.053 | 0.070 | 0.067 | 0.060 | 0.447 | 0.064 |
| FL | 0.128 | 0.053 | 0.023 | 0.053 | 0.023 | 0.067 | 0.060 | 0.405 | 0.057 |

## *5.4 Calculation of consistency ratio for the each of the pair-wise comparison matrices*

The next stage is to calculate a consistency ratio ($C_R$) to measure how consistent the judgements have been made relative to large samples of purely random judgements. The consistency ratio is an approximate mathematical indicator which provides consistency of pair-wise comparisons (Canada and Sullivan, 1989). Consistency ratio for the comparison matrix would be within a 0.10, which is the empirical upper limit suggested by Saaty. If the consistency ratio is greater than 0.10 the judgements are untrustworthy and the pair wise analysis must be repeated for consistency. In general, lower the consistency ratio, higher is the accuracy of priority weights. Mathematically, consistency ratio can be expressed as the ratio of the consistency index to the random index, which is shown by equation (1).

$$C_R = \frac{CI}{RI} \tag{1}$$

where $C_R$ is consistency ratio, $CI$ is consistency index and $RI$ is random index.

Consistency index for a matrix size '$n$' is given by the following formula.

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

where $\lambda_{\max}$ is maximum eigenvalue and $n$ is size of the matrix.

Random index (RI) can be obtained from simulation runs and depends upon the order of matrix. Table 16 shows the average values of RI for the matrices of order 1–10 (Saaty, 1980).

**Table 16** Random index (RI) based on matrix order ($n$)

| Size of matrix ($n$) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Random Index (RI) | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

**Table 17** Consistency ratio ($C_R$) of the each of the comparison matrices

| *Comparison matrix* | *Consistency ratio ($C_R$)* |
|---|---|
| Pair-wise comparison of ranking criteria | 0.030 |
| Pair-wise comparison of enablers with respect to competency | 0.025 |
| Pair-wise comparison of enablers with respect to robustness | 0.058 |
| Pair-wise comparison of enablers with respect to responsiveness | 0.059 |
| Pair-wise comparison of enablers with respect to cost-effectiveness | 0.083 |
| Pair-wise comparison of enablers with respect to quickness | 0.048 |

Maximum eigenvalue ($\lambda_{\max}$) is calculated in order to obtain $C_R$. To calculate maximum eigenvalue ($\lambda_{\max}$), first multiply the matrix of pair-wise comparisons (say matrix A) by priority weight (matrix B) to get new matrix C [equation (3)]. In next step, divide each element in vector [C] by its corresponding element in vector [B] to find a new vector [D] [equation (4)]. Now, average the elements in vector [D], which can be called as maximum eigenvalue and denoted by $\lambda_{\max}$. Table 17 shows the $C_R$ of the each of the comparison matrices.

$$[A]*[B]=[C] \tag{3}$$

$$[D]=\frac{[C]}{[B]} \tag{4}$$

Applying above expression, consistency ratio of the each of the comparison matrices were calculated and tabulated in Table 17. It can be observed that, consistency ratio of the each comparison matrix is less than Saaty's empirical suggestion (which is 0.10). Hence, it can be inferred that good consistency was found in the judgments made by experts.

## *5.5 Computation of the overall weights of the ASC enablers*

In order to compute overall AHP weights of ASC enablers, AHP combines the priority weights of criteria with the priority weights of ASC enablers with respect to each criterion. The overall weight of the ASC enablers ($w_{ei}$) can be obtained by multiplying the priority weights of enablers ($w_{eij}$) to the priority weights of selection criteria ($w_{cj}$) and summing over all criteria. Equation (5) is expression for the calculation of weights of ASC enablers.

$$w_{ei} = \sum_{j=1}^{5} \left( w_{eij} * w_{cj} \right) \tag{5}$$

$$w_{ei} = \begin{bmatrix} 0.349 & 0.107 & 0.347 & 0.214 & 0.363 \\ 0.196 & 0.099 & 0.068 & 0.154 & 0.177 \\ 0.037 & 0.064 & 0.211 & 0.294 & 0.081 \\ 0.037 & 0.113 & 0.068 & 0.048 & 0.177 \\ 0.196 & 0.288 & 0.042 & 0.188 & 0.081 \\ 0.93 & 0.280 & 0.132 & 0.061 & 0.064 \\ 0.092 & 0.049 & 0.132 & 0.041 & 0.057 \end{bmatrix} * \begin{bmatrix} 0.285 \\ 0.475 \\ 0.084 \\ 0.078 \\ 0.078 \end{bmatrix}$$

$$w_{ei} = \begin{bmatrix} 0.224 \\ 0.134 \\ 0.088 \\ 0.087 \\ 0.217 \\ 0.181 \\ 0.069 \end{bmatrix}$$

### *5.6 Analysis of results*

The results of the present study are consolidated in Tables 18 and 19. Table 18 shows priority weights of the criteria and Table 19 shows overall weights and rank of seven ASC enablers. From Table 18, it was analysed that criteria robustness has maximum priority (0.475) based on the fact that the case-organisation being considered in this study can strongly withstand variations and disturbances arrived in the business environment. For example, while considering demand pattern of the case-organisation, there is uncertainty in customer demand. Due to this uncertainty, the case-organisation analyses the demand pattern; forecasts demand for two years based on previous data and hence, procure components and spares accordingly. Competency (0.285) is the second most important criteria. It is because the case-organisation can effectively and efficiently achieve its target goals. Target goals include an on-time delivery, producing a high-quality product, safety of workers and so on. It was evident that case-organisation delivers a completed high-quality product on the schedule that fulfil the commitments to customers and also strives to reduce the potential for injury on the manufacturing floor. Remaining three criteria namely responsiveness (0.084), cost-effectiveness (0.078) and quickness (0.078) were found to be of secondary or lesser importance. It is mainly due to reasons that case-organisation take more time and money to identify and respond to changes and disturbances.

**Table 18** Resulting priority weights for each criterion

| *Criterion decisions* | *Priority weights* |
|---|---|
| Competency | 0.285 |
| Robustness | 0.475 |
| Responsiveness | 0.084 |
| Cost-effectiveness | 0.078 |
| Quickness | 0.078 |

**Table 19** Overall AHP weights and ranking of the ASC enablers

| *ASC enablers* | *Overall AHP weights of enablers* | *Rank of the enablers* |
|---|---|---|
| Virtual enterprises | 0.224 | 1 |
| Collaborative relationship | 0.134 | 4 |
| Use of IT | 0.088 | 5 |
| Market sensitivity | 0.087 | 6 |
| Customer satisfaction | 0.217 | 2 |
| Adaptability | 0.181 | 3 |
| Flexibility | 0.069 | 7 |

**Figure 3** Comparison of ASC enablers with respect to their overall priority weights

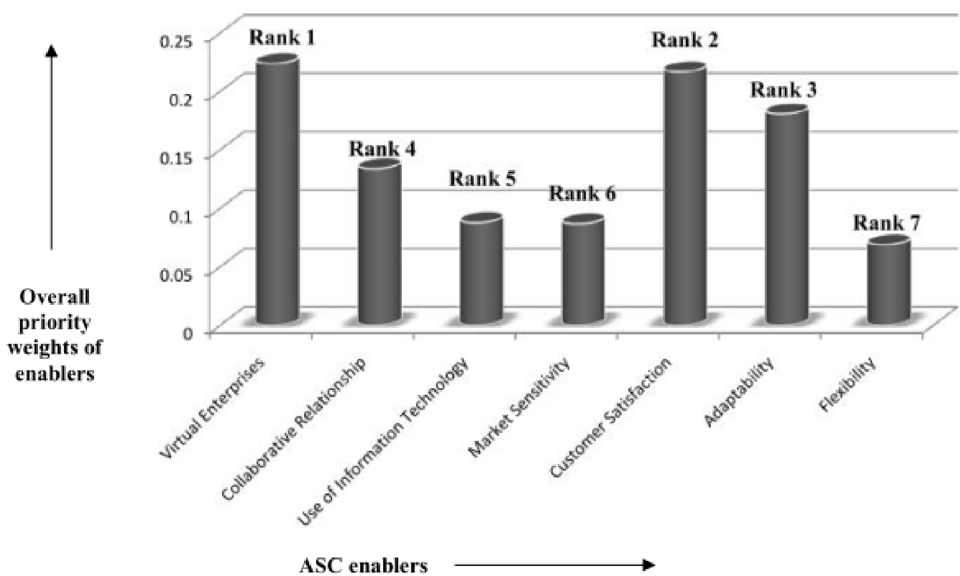



Table 19 indicates that an enabler virtual enterprise (0.224) is the most important enabler among the seven ASC enablers and hence is ranked first. The evident reason is that the case-organisation focuses more on the virtual enterprise by alliance to some other companies to share their skills or core competencies and resources in order to better respond to customer demand. The second highest overall priority weight is of the CS (0.217). CS is one of the most important enabler due to the reason of key issues to survival. Case-organisation continuously understands and provides what their customers want. It provides quality assurance, customer service and also takes regular feedback from customers. Adaptability has third highest global weight which is equal to 0.181. Hence, adaptability was given third preference. From Figure 3, it can be seen that adaptability is closer to VE and CS. This implies that case-organisation also prefer adaptability in their supply chain. The case-organisation correctly predicts and responds to an unexpected change in their business environment.

CR is next to adaptability with priority weight 0.134 and global rank of 4. Here, CR refers to close and coordinated relationships between the case-organisation and their supply chain partners. The case-organisation builds CRs with their major business partners in order to achieve efficiency, flexibility, and sustainable competitive advantage. It is observed that with the help of CR, the risk in supply chain can be managed effectively. Next three enablers i.e., use of IT (0.088), marketing sensitivity (0.087) and flexibility (0.069) are derived as fifth, sixth and seventh rank respectively. Comparison of their priority weights (Figure 3) shows that these three enablers are almost close to each other and hence, enjoy almost equal importance. These three enablers may also important for the case-organisation but decision maker focuses according to their preferences. Use of IT helps to minimise human errors, eliminate non-value adding activities and improve productivity and quality of production. With the help of marketing sensitivity supply chain manager of case-organisation can read and respond to real demand which can also help to quickly introduction of the new products in the market. Flexibility in a case-organisation ensures smooth undisrupted supply of product from supplier to the end user.

## *5.7 Generality of the model*

The findings of this study can be useful for other manufacturing organisations with a view to make them agile. Mostly every manufacturing organisations face common business environments such as uncertainty, global competition, and complexity. The production systems of the manufacturing organisations may be small, medium or large but they all are involved in the practice of partner selection, outsourcing, and procurement of raw materials or semi-finished product in order to manufacture the final products. For this purpose, they may in need of making a temporary alliance or collaboration with other enterprises in order to fulfil their customer requirements. Again, as most of the manufacturing organisations have the almost similar type of production planning and control process; they all use latest IT es tools as it is a major concern for them to be aware of the real demand of product and changes therein. For this purpose, analysing the market trends, forecasting the demand and surveying the markets is very important. CS is an important aspect of all the manufacturing organisations. Therefore, controlling the quality of the product, providing quality assurance and customer service to their customers are vital requirement of today’s business. These are the main reasons that the manufacturing organisations are in need of making their supply chain flexible to be competitive under dynamic business environments.

## 6 Conclusions and future scope

Organisations have realised that agility is a key determinant of competitiveness in today's dynamic and turbulent business environment. Therefore, it is imperative to incorporate agility in supply chains for survival in turbulent and volatile markets. Thus, it is required to identify the most appropriate enablers to be implemented by companies. 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 ASC. It is required to work with all agility enablers, but it is not economical and efficient to give same focus and attention to all agility enablers.

### *6.1 Contributions to the research*

In this research paper, an AHP model is developed to investigate and prioritise the ASC enablers for an Indian manufacturing organisation. The model presented in this study would help the practitioners to assign relative importance to various agility enablers in a supply chain and then give focus and attention to each enabler based on their importance. Considering above facts, seven ASC enablers from the Indian manufacturing context were chosen based on literature review and experts' opinion. These seven enablers are VE, CR, use of IT, MS, CS, adaptability, and flexibility.

### *6.2 Key findings and observations*

From the results, it can be observed that enablers like VE, CS, and adaptability are among the top priority enablers; enabler CR is the moderate priority enabler and remaining three enablers such as the use of IT, MS and flexibility are the lowest priority enablers. To effectively implement agility in the supply chain, manufacturing industries need to focus on the most important ASC enablers and address the least important enablers at a later stage as proposed in the current work.

### *6.3 Managerial implications*

The proposed AHP model would help the supply chain manager to assign relative importance to various agility enablers in given case-organisation. In general, to effectively implement agility in the supply chain, manufacturing industries should focus on the most important ASC enablers and also address the enablers, one with the least important at a later stage as suggested in the present work. AHP model developed in this research will be useful to decision-makers in manufacturing industries as a guideline for implementing agility in their supply chains.

### *6.4 Scope for future work*

In this research, only seven enablers were considered from the perspective of the Indian manufacturing organisation. Future studies on this subject can deal with investigation and analysis of more enablers. Such studies can be conducted for different organisations to analyse ASC enablers extensively. In this problem, the AHP method was used as the MCDM method whereas other MCDM approaches can also be used in the future.

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## Notations

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|---|---|
| $i$ | enablers' index, $i$ = 1 to 7 |
| $j$ | criteria' index, $j$ = 1 to 5 |
| VE | virtual enterprises |
| CR | collaborative relationship |
| IT | information technology |
| MS | market sensitivity |
| CS | customer satisfaction |
| AD | adaptability |
| FL | flexibility |
| $C_R$ | consistency ratio |
| CI | consistency index |
| RI | random index |
| $\lambda_{max}$ | maximum eigen value |
| $n$ | size of the matrix |
| $w_{ei}$ | overall weight of enabler $i$ |
| $w_{eij}$ | priority weight of enabler $i$ with respect to criterion $j$ |
| $w_{cj}$ | weight of selection criterion $j$. |