Marketing Intelligence & Planning

A hybrid PCA-AHP-Multi-grade Fuzzy approach to assess marketing-based flexibility

Ruchi Mishra, Onkar Nath Mishra,

A hybrid PCA-AHP-Multi-grade Fuzzy approach to assess marketing-based flexibility

Ruchi Mishra
Department of Operations and Decision Science, Birla Institute of Management Technology, Greater Noida, India, and
Onkar Nath Mishra
Andor Communications Private Limited, Delhi, India

Received 23 July 2017
Revised 8 October 2017
29 October 2017
1 November 2017
Accepted 1 November 2017

Abstract

Purpose – The purpose of this paper is to propose a novel hybrid approach to assess marketing-based flexibility with respect to its source factors, enablers and attributes.
Design/methodology/approach – The study demonstrates an application of a hybrid principal component analysis (PCA)-analytical hierarchical process (AHP)-multi-grade fuzzy approach (MFA) to measure marketing-based flexibility. Using PCA method, attributes, enablers and source factors of marketing-based flexibility were identified and a conceptual model was developed. AHP and MFA were used to compute marketing-based flexibility index.
Findings – The proposed approach measures existing level of marketing-based flexibility and therefore it identifies weak areas that should be taken care to improve flexibility.
Research limitations/implications – The scope of the study is limited to plant level. The validity of the proposed approach is shown using a case study. For generalisation point of view, the application of this proposed approach should be investigated in a large number of firms in different industrial settings.
Practical implications – The study gives a reliable and valid method, which combines both statistical and MCDM techniques to measure existing level of flexibility and identify weak areas for flexibility improvement.
Originality/value – The findings provide insight into factors that should be worked upon to improve flexibility.

Keywords Marketing, Measurement, Surveys, Flexibility, MCDM, Index

Paper type Research paper

1. Introduction

Business firms competing in today's hyper competitive uncertain environment need to develop a market-driven approach (Filieri, 2015). Since market-driven organisations largely depend on their ability to respond quickly and effectively (Didonet *et al.*, 2012), flexibility becomes one of the important capabilities to compete in the market. In manufacturing literature, flexibility is classified into manufacturing-based flexibility and marketing-based flexibility (Chen *et al.*, 1992). Marketing-based flexibility directly affects market orientation of the firm and represents the outcome of manufacturing-based flexibility; therefore, it is important that a firm must develop marketing-based flexibility to improve its competitive position. Further, considering the major role of marketing-based flexibility in competitiveness, it is essential to assess existing flexibility of a firm.

Despite the widespread importance of marketing-based flexibility, majority of the studies is limited to manufacturing-based flexibility (Chuu, 2005) and there are few studies that assess how firms develop marketing-based flexibility to compete in the marketplace. Although, a variety of approaches, such as EFA (Koste *et al.*, 2004), G theory (Malhotra and Sharma, 2008), analytical hierarchical process (AHP) (Mishra *et al.*, 2017), fuzzy set theory (Chuu, 2005; Das and Caprihan, 2008) have been used to quantify and assess single or multiple dimensions of flexibility, studies have not been done to assess marketing-based flexibility in terms of its source factors. Since marketing-based flexibility is determined by the flexibility of its source factors, it is important to assess marketing-based flexibility in

Marketing Intelligence & Planning

0263-4503
DOI 10.1108/MIP-07-2017-0144

terms of its source factors. To address this gap, the aim of the study is threefold: first, it identifies important factors that influence marketing-based flexibility in firms; second, it aims to develop a marketing-based flexibility index to assess the existing flexibility level in firms; third, it attempts to highlight the weak areas that should be taken care to improve the flexibility level in firms.

This study proposes a hybrid approach to assess marketing-based flexibility and demonstrate the application of the approach in Indian apparel firms. Indian firms are selected mainly due to following reasons: flexibility implementation practices are considerably low in India (Mishra *et al.*, 2017); compared to developed nations, Indian firms give highest priority to quality and least priority to flexibility (Dangayach and Deshmukh, 2005); adoption of advanced manufacturing technologies (AMTs) at shop-floor level is really low and Indian firms give more emphasis on simple, standalone and less capital intensive AMTs compared to AMTs, which require considerable investments and demand integration among different technologies (Thakur and Jain, 2008).

The rest of the paper is structured as follows. In Section 2, background literature is provided. Section 3 describes research methodology and Section 4 presents results of principal component analysis (PCA). Section 5 illustrates marketing-based flexibility assessment model and Section 6 presents discussion and managerial implications of the study. The conclusion, limitations and future scope are described in Section 7.

2. Background literature

2.1 Marketing-based flexibility

The concept "flexibility" has been defined and classified by several authors using diverse nomenclature (Beach *et al.*, 2000; Vokurka and O'Leary-Kelly, 2000; Chang *et al.*, 2005). Literature has classified flexibility into two broad categories: manufacturing-oriented flexibility and marketing-oriented flexibility (Chen *et al.*, 1992; Beach *et al.*, 2000). Other studies have also proposed and supported similar kind of classification using different nomenclatures, such as type I and type II flexibility (Carlsson, 1989 in Beach *et al.*, 2000) and external and internal flexibility (Upton, 1994). Since environmental uncertainty is considered driver of flexibility (Mishra *et al.*, 2014a), studies have defined marketing- and manufacturing-based flexibility based on their ability to deal with uncertainties (Upton, 1994). In an early study, Chen *et al.* (1992) broadly classified flexibility into two categories: manufacturing-based flexibility and marketing-based flexibility. They suggested that "marketing-based flexibility, which consists of product, volume, mix and expansion flexibilities, is concerned with the capability to cope up with the dynamic market changes, whereas manufacturing-based flexibility deals with the flexibility inherent in the manufacturing resources". Despite these diverse terminologies, it can be concluded that marketing-based flexibility is required to cope with the external environmental uncertainties, whereas marketing-based flexibility is used to deal with internal environmental uncertainties.

2.2 Enablers of marketing-based flexibility

Enablers are the factors that assist in providing marketing-based flexibility (Mishra *et al.*, 2014a). Studies are available on different enablers that influence marketing-based flexibility (Chang *et al.*, 2005; Zhang *et al.*, 2006; Poolton *et al.*, 2006). One of the most extensively studied factors in enabling marketing-based flexibility is AMTs. Similarly, design and behavioural aspects of firms are also considered as an important enabler for flexibility (Vokurka and O'Leary-Kelly, 2000). As an example, Kathuria and Partovi (1999) explored how workforce management practices contribute to better managerial performance when emphasis on flexibility is high. Managerial emphasis on flexibility (Upton, 1995), employee participation in problem-solving activity (Urtasun-Alonso *et al.*, 2014), skill-based compensation (Urtasun-Alonso *et al.*, 2014),

workforce training with new skills (Upton, 1995; Chang *et al.*, 2005; Urtasun-Alonso *et al.*, 2014), workforce experience (Upton, 1995), workforce management practices (Kathuria and Partovi, 1999) are some of the factors that have been explored with respect to their relationship with marketing-based flexibility.

Recent studies have explored role of integration practices in marketing-based flexibility (Chang *et al.*, 2005; Swink *et al.*, 2007). Integration practices encourage cross-functional communication and give an opportunity to understand limitations and strength of others' function, thereby, positively influence flexibility (Swink *et al.*, 2007). Several manufacturing improvement practices also play an important role in enabling marketing-based flexibility (Zhang *et al.*, 2006). Further, few studies have investigated role of suppliers and strategic sourcing in realising flexibility (Chang *et al.*, 2006; Mishra, 2016). Chang *et al.* (2006) stated that "supplier involvement could be a valuable source to develop capability based flexibility that is difficult to imitate". Logman (2008) stated how strategic moves along with different contextual dimension make companies flexible. Further, recent studies have investigated role of different factors that influence marketing-based flexibility (Mishra *et al.*, 2017).

2.3 Assessment of flexibility

This section reviews studies done in the areas of assessment of marketing- and manufacturing-based flexibility.

2.3.1 Conceptual papers. Conceptual studies have primarily focussed on frameworks related to assessment and management of flexibility (Gerwin, 1993; Boyle, 2006). Gerwin (1993) developed a four-phase approach for implementation of flexibility. Narain *et al.* (2000) proposed that an organisation should first assess environmental uncertainties and then evaluate these environmental uncertainties against firms' capabilities. In a relatively recent research, Mishra *et al.* (2014a) proposed a manufacturing flexibility assessment framework by considering a set of flexibility enablers and drivers.

2.3.2 Empirical papers. Empirical studies have focussed on development and validation of measurement instruments (Gupta and Somers, 1992; Koste *et al.*, 2004; Malhotra and Sharma, 2008) and investigation of factors that influence manufacturing flexibility at plant level (Mishra *et al.*, 2014b) through case study and survey approach. In an early literature, Gupta and Somers (1992) proposed 21 items validated questionnaire for measuring nine elements of manufacturing flexibility. Further, Koste *et al.* (2004) developed 24 items questionnaire for measuring six dimensions and their associated four elements of manufacturing flexibility. In a similar way, Malhotra and Sharma (2008) examined generalisability of earlier scale developed by Koste *et al.* (2004).

Oke (2005) extended earlier framework and identified various enablers (sources) of manufacturing flexibility. The three types of enablers – fundamental enablers, indirect enablers and generic enablers of volume and product mix flexibility as well as flexibility evaders were identified. Further, various survey-based studies have investigated the relationship between various antecedents, such as AMTs, human resource practices, manufacturing and operational improvement practices, supplier-related factors and manufacturing flexibility (Hallgren and Olhager, 2009; Urtasun-Alonso *et al.*, 2014; Mishra, 2016).

2.3.3 Other research. Studies have used variety of mathematical models, simulations and operation research techniques to measure and evaluate dimensions of manufacturing flexibility at plant level (Wang and Chuu, 2004; Chuu, 2005; Mishra *et al.*, 2017). Several studies have developed flexibility measurement approaches using combinations of methods. The majority of these frameworks incorporated uncertainty elements into decision making. Wang and Chuu (2004) developed a group decision-making framework to measure degree of flexibility of a system in a fuzzy environment. Further, Chuu (2005) developed a multi-attribute decision-making model based on fuzzy set theory to measure manufacturing flexibility.

Further, Das and Caprihan (2008) incorporated three elements of manufacturing flexibility, i.e. relative importance, manifestation level and state change efficiency of a factor while computing index value of flexibility.

The above studies suggest that many studies have been done on measurement aspects of flexibility, but none of the studies assessed marketing-based flexibility with respect to its source factors (Mishra *et al.*, 2014b). In this context, this study develops a conceptual model based on literature, followed by refinement of this model using a hybrid method to evaluate marketing-based flexibility of a firm.

3. Research methodology

3.1 Methods used in hybrid approach

3.1.1 PCA. PCA is a multivariate technique that reduces dimensionality of a set of interrelated variables while retaining maximum possible variations present in the data set (Hair *et al.*, 2010). PCA is applied to transform a set of correlated observational variables into a set of linearly uncorrelated variables, referred as principal components, obtained from eigenvalues and eigenvectors of covariance matrix. In this study, PCA with varimax rotation was applied on a set of data to determine dimensionality of 53 attributes (measurement items) that account for maximum amount of variance.

3.1.2 AHP. AHP, developed by Saaty (1980), is one of the most widely used multi-criteria decision-making method. Using eigenvalue approach, AHP offers flexibility to incorporate both qualitative and quantitative elements and group consents in a complex decision-making scenario. The scale of 1-9 is used for $n(n-1)/2$ pairwise comparisons, where score of 1 represents "equal importance" and 9 represent "absolute importance of one component over another". The consistency of the pairwise comparisons was checked using consistency index (CI) and consistency ratio (CR).

3.1.3 Multi-grade fuzzy approach (MFA). In recent years, MFA has been widely used in the field of operations management, particularly in the area of leanness and agility assessment (Yang and Li, 2002). Multi-grade fuzzy assessment involves assessment of attributes on five-point fuzzy grade, i.e. $I = \{10, 8, 6, 4, 2\}$. Each attribute is identified using PCA and evaluated by assigning an assessment grade. Here, value of (8-10) signifies "extremely flexible", (6-8) signifies "flexible", (4-6) signifies "generally flexible", (2-4) signifies "not flexible" and the value less than 2 signifies "extremely rigid". Therefore, if an attribute is assigned a value of 8, it means that particular attribute is extremely flexible in addressing the variability, whereas, the value of 1 represents rigidity and non-flexibility of a particular attribute.

3.2 Rational for using hybrid method

The study employs a hybrid method for computation of marketing-based flexibility due to relative advantages associated with each of PCA, AHP and MFAs. Unlike conventional statistical methods, a hybrid method is proposed to effectively handle problems associated with imprecise information and multiple criteria in decision making. The first step involves identification of different factors that influence marketing-based flexibility using literature. Consequently, due to its simplicity, ease of use and ability to handle non-parametric data, PCA has been used to explore a set of factors, known as principal components that account for maximum amount of variance in a data set (Hair *et al.*, 2010).

Once different factors (enablers hereafter) and their associated variables (attributes hereafter) were derived from PCA, in the next step, enablers were group into source factors. AHP is used to determine the relative importance of these attributes, enablers and source factors. AHP proves more beneficial than conventional approaches in a group decision-making problems due to its ease of applicability and flexible structure. AHP is extensively

used either standalone or integrated with other methods, such as LP, QFD and DEA in the diverse areas due to its wide applicability, strength, flexibility and ease of use. Studies have also reviewed articles related to AHP and classified these articles based on different themes and areas of applications (Sipahi and Timor, 2010; Ishizaka and Labib, 2011; Subramanian and Ramanathan, 2012).

In the next step, experts' opinion about the level of flexibility of each of these attributes in the case firm was taken. MFA was used to capture the subjectivity, imprecision and vagueness involved in experts' judgement (Yang and Li, 2002). Fuzzy logic attempts to capture "degree of truth" rather than binary response and gives more realistic evaluation by using linguistic assessment rather than numerical value (Chuu, 2005). Here, assessment grade $(U) = (10, 8, 6, 4, 2)$ is used wherein 8-10 points means extremely strong, 6-8 means strong, 4-6 means generally strong, 2-4 means weak and under 2 means extremely weak (Yang and Li, 2002).

3.3 Extraction of enablers and their attributes using PCA

3.3.1 Instrument development. A 53 items self-reporting questionnaire was developed to measure ten latent constructs. The definitions and measures of these ten latent constructs were taken from literature and reworded for our research setting. The definitions of "Design and manufacturing technology (DMT)", "Planning and Integration technology" and "Manufacturing improvement practices" were adapted from Zhang *et al.* (2006). "Workforce improvement practices" and "marketing and manufacturing integration" were defined as per the definition of Chang *et al.* (2005). The definitions of "purchasing flexibility" and "supply flexibility" were adapted from Zhang *et al.* (2005). The definitions of "product/process technology integration" and "customer integration" were adapted from Swink *et al.* (2007). "Supplier development practices" were defined as per the definition of Wagner and Krause (2009).

3.3.2 Target population and sample. The target population of the study consists of apparel manufacturing firms located in India. The list of total 311 Indian apparel manufacturing firms (NAICS code: 315) were obtained from Emerging Markets Information Service database as on January 2017. The targeted respondents include practitioners working in manufacturing, supply chain, design, production planning and control and logistics domains.

Due to small population size, initial attempt was made to contact all the firms through e-mails, telephonic calls and professional networking site – Linkedin. Out of these 311 firms, 189 firms shown their willingness to participate in this study. Using purposing and snowball sampling, the targeted respondents were contacted through personal contacts, professional networking sites and through referral of friends and HR managers. Each questionnaire in the survey was put to two or three respondents in each firm. In order to increase the response rate, a total 378 questionnaires were sent to total 189 apparel firms located in different regions of India. After sending two/three reminders and follow-up telephone calls, a total 178 responses, representing a response rate of 47.08 per cent were achieved. After the initial screening, total 11 responses were found unusable representing a final 167 complete responses from 97 firms. The respondents' profile consisted of a broad range of profiles, such as CEO, general manager, plant manager and warehouse manager, etc. with a minimum of nine responses per position.

3.3.3 Common method bias (CMB) and non-response bias assessment. CMB was controlled using design of the study's procedures and statistical control method. Under design of the study's procedures, response anonymity was maintained during data collection phase and questionnaires items were carefully constructed by defining unfamiliar and eliminating confusing words (Podsakoff *et al.*, 2003). The result of Harman's single factor test accounted for only 9.83 per cent variance in the model confirming the absence of CMB. Non-response bias was assessed using subjective method. A random sample of non-respondents were contacted and asked reason for their non-participation.

The paucity of time and need to take formal permission to fill out any survey form were identified as main reasons of non-response, confirming the absence of non-response bias.

Further, Cronbach's coefficient α and item to total correlation were found greater than 0.7 and 0.3, respectively. Accordingly, there was no need to modify the scale at this stage.

3.3.4 PCA and sample size requirement. The study has applied PCA on a data set of 167 observations. The two sets of recommendations are given regarding the sample size requirement for PCA: absolute number of sample size (N) and subject to variable ratio (STV). Different rules exist in literature regarding absolute sample size, such as rule of at least 100 (Kline, 1999 in MacCallum *et al.*, 1999), rule of at least 200 (Guilford, 1954 in MacCallum *et al.*, 1999). Similarly, different set of recommendations are available for STV, such as rule of 3:1 (Guadagnoli and Velicer, 1988 in Gorsuch, 1997), rule of 10:1 (Everitt, 1975 in MacCallum *et al.*, 1999).

Despite these diverse recommendations, choice of appropriate sample size largely depends on the nature of data (MacCallum *et al.*, 1999). Guadagnoli and Velicer (1988) in Gorsuch (1997) reported that "if the data set has several high factor loading (>0.80), then a smaller sample size ($n > 150$) should be sufficient". The result of PCA gives high value of communalities (>0.60) and factor loadings (>0.70), therefore, a homogenous sample of 167 observations represents a strong data set.

3.3.5 Results of PCA. PCA using varimax rotation was applied with the factor loading cut-off criteria of equal or greater than ±0.5 (Zhang *et al.*, 2006). Hair *et al.* (2010) suggested that "factor loadings in the range of ±0.3 to ±0.4 are considered minimal acceptable level for interpretation of factor structure, whereas loading ±0.5 or greater are considered practically significant for interpretation". After three iterations, the result depicted a solution of ten factors that exhibited eigenvalues >1 and explained 72 per cent of variance. The value of KMO was 0.71. All communalities were >0.6 and non-redundant residuals were 142 (9 per cent) representing a very good model fit. All measurement items had factor loading greater than 0.70 on their respective constructs and less than 0.3 on other constructs, satisfying the requirement of convergent and discriminant validity.

4. Marketing-based flexibility assessment model and numeric example

4.1 Marketing-based flexibility assessment model

The ten enablers derived from PCA were further grouped into four broad categories (referred as source factors hereafter), namely, technological capabilities, organisational improvement practices, integration practices and logistics flexibility.

A three-tier hierarchical conceptual model was developed by taking consensus from five experts (Figure 1). First level comprised of source factors, second level comprised of enablers and third level included underlying attributes of enablers, which were derived from PCA.

This study computes marketing-based flexibility index of a firm as the function of indices of underlying source factors. The indices of these source factors are based on

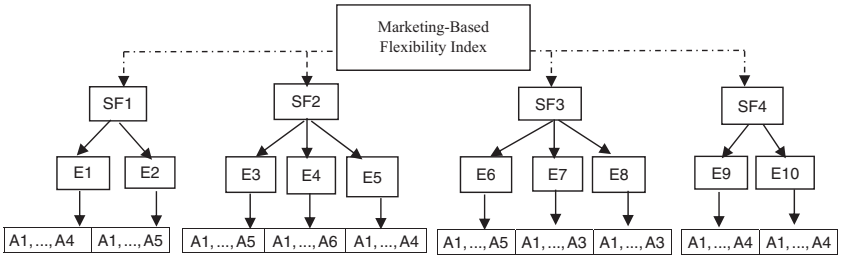

Figure 1.
Conceptual model

Notes: SF = Source Factor; E = Enabler; A = Attribute

importance weight of enablers and assessment rating of attributes. Marketing-based flexibility index matrix of the firm can be represented as follow:

$$\text{MFI} = \begin{bmatrix} I_{TC} \\ I_{OIP} \\ I_{IP} \\ I_{LF} \end{bmatrix}$$

where MFI is the marketing-based flexibility index matrix of the firm; I_{TC} the index matrix of technological capability (TC); I_{OIP} the index matrix of organisational improvement practices; I_{IP} the index matrix of integration practices; and I_{LF} the index matrix of logistics flexibility.

4.2 Problem description

Marketing-based flexibility is one of the essential capabilities that is required to compete in today's market, however, assessment of flexibility remains a challenge for firms. This study demonstrates an application of proposed hybrid approach in a fashion apparel firm located in Northern part of India. The case firm X manufactures a wide range of women and kid apparel products and utilises latest technology in each stage of production process. This firm requires high level of marketing-based flexibility in its production process to address demand variability caused by changing market needs in its different product categories. Therefore, assessment of current level of marketing-based flexibility is required to transform and leverage its asset base.

4.3 Case analysis

4.3.1 Phase I: determination of importance weight of attributes, enablers and source factors.

In this phase, the importance weight of attributes, enablers and source factors of marketing-based flexibility was computed using AHP. The importance weights of attributes and enablers were derived based on the relative importance of attributes to enablers and relative importance of enablers to their source factors. The importance weights of source factors were computed based on their relative importance to marketing-based flexibility. The different steps involved in this process are as follows.

Step 1: develop pairwise comparison matrices for attributes, criteria and source factors. In the first phase, flexibility assessment model and the feasibility of the study were discussed with decision-making group comprising of five senior members from manufacturing, supply chain, design, production planning and marketing domain. The members of the decision-making groups were selected based on: experience of at least seven years in similar domain; experience in existing organisation for more than three years; and awareness about importance and application of flexibility concept.

After the approval of decision-making group, using nine-point AHP scale, pairwise comparisons between different attributes, enablers and source factors were done as per the three-tier hierarchical structure of the assessment model.

Step 2: calculation of importance weight and consistency in experts' judgements. The relative importance weights of different attributes, enablers and source factors were computed using Expert Choice software (Table I). As an example, importance weight of different attributes of DMT was found as follows:

$$W_{DMT} = \begin{bmatrix} W_{CAD} & W_{AMT} & W_{MF} & W_{AI} \end{bmatrix} = \begin{bmatrix} 0.36 & 0.18 & 0.32 & 0.14 \end{bmatrix}$$

where W_{CAD}, W_{AMT}, W_{MF} and W_{AI} represent relative importance weight of attributes for enabler "DMT".

Table I.
Attributes assessment rating and importance weight of attributes, enablers and source factors

Source factors	Enablers	Attributes	S*	E*	A*	E1	E2	E3	E4	E5
Technological capabilities (TC)	Design and manufacturing technology (DMT)	Use of CAD in product and process design (CAD)	0.20	0.67	0.36	8	7	8	7	8
		Use of AMTs to control processes and produce physical products (AMT)			0.18	6	7	6	5	5
		Usages of modern fusing and pressing machine (MF)			0.32	7	8	6	7	6
		Use of automated inspection (AI)			0.14	6	4	6	5	4
	Planning and integration technology (PIT)	Utilisation of advanced MRP systems (MRP)		0.33	0.09	8	7	8	7	6
		Usage of ERP systems (ERP)			0.20	6	7	8	7	5
		Use of EDI system (EDI)			0.18	5	7	8	6	5
		Use of LAN and WAN to allow flow of information (LAN/WAN)			0.34	7	8	8	8	8
		Use of RFID technologies to track flow of inventories (RFID)			0.19	4	5	4	3	5
Organisational improvement practices (OIP)	Workforce improvement practices (WIP)	Workforce training for new operating skills (WT)	0.29	0.26	0.35	4	5	6	5	8
		Offering manufacturing workers a broad range of tasks (MW)			0.31	3	6	5	8	7
		Delegating more planning and quality control responsibility to workers (PC)			0.09	6	5	4	7	7
		Executing skills-based compensation (SC)			0.06	3	4	5	4	6
		Participation in the formal problem-solving activities (FP)			0.19	4	5	4	5	6
	Manufacturing improvement practices (MIP)	Redesigning set-ups for operations improvements (SO)		0.41	0.14	5	5	6	5	6
		Preventive maintenance for operations improvement (PM)			0.06	4	5	5	6	7
		Just-in-time principles for operations improvements (JIT)			0.31	6	5	4	5	7
		Pull production for operations improvements (PP)			0.24	5	7	6	7	6
		Statistical techniques to reduce variance in the processes (ST)			0.11	4	6	5	5	7
		Products are designed to use many common modules (CM)			0.14	5	5	6	6	5
	Suppliers development practices (SDP)	Suppliers' training to develop product development capabilities (ST)		0.33	0.30	9	8	9	7	8
		Strong formal suppliers' evaluation (SE)			0.38	7	5	7	6	6
		Manufacturing and technology related advice to suppliers (MT)			0.21	5	6	4	6	5
		Transferring suppliers' employee to firm or vice versa (ST)			0.11	4	6	6	7	4

(*continued*)

Table I.

Source factors	Enablers	Attributes	S*	E*	A*	E1	E2	E3	E4	E5
Integration practices (IP)	Product/process technology integration (PPTI)	Design-for-manufacture/assembly methods (DFMA)	0.16	0.26	0.14	7	6	6	8	6
		Job rotations between design and manufacturing departments (JR)			0.24	6	8	8	6	5
		New ways of coordination of design and manufacturing issues (DMC)			0.15	5	6	7	6	6
		Usage of product data management systems (PDM)			0.09	6	7	6	8	7
		Frequent interactions between new product design team and manufacturing function (INM)			0.38	8	6	7	6	6
	Customer integration (CI)	Customer involvement at each stage of production (CI)		0.41	0.31	9	8	9	7	8
		Formal "customer satisfaction" programmes in place (CS)			0.20	7	9	9	8	7
		Close contacts with customers (CC)			0.49	8	9	8	7	6
	Marketing and manufacturing integration (MMI)	Handling of customer order by manufacturing and marketing department (HCO)		0.33	0.33	7	6	8	7	5
		Improving communication between manufacturing and marketing department (IC)			0.14	6	7	7	6	6
		Use of marketing sales forecasts for capacity planning and production scheduling (CP)			0.53	8	5	6	6	5
Logistics flexibility (LF)	Purchasing flexibility (PF)	Ability to quickly get different materials as per specifications (PM)	0.35	0.33	0.30	5	6	4	4	5
		Ability to quickly get multiple batch sizes of materials from suppliers (MS)			0.17	6	5	6	7	5
		Close communication between purchasing department and suppliers (CC)			0.12	6	6	7	6	5
		Joint working with suppliers on products and process specifications (PP)			0.41	6	8	6	7	6
	Supply flexibility (SF)	Delivery of multiple kinds of materials as per the requirements (DM)		0.67	0.42	4	5	6	6	5
		Picking and assembling of orders accurately and quickly at the warehouse (PA)			0.26	6	5	4	5	5
		Ability to quickly move materials to the correct production location (QM)			0.17	4	5	6	6	7
		Accurate records of quantities and locations of inventory at the material warehouse (AR)			0.15	7	8	7	7	6

Notes: S*, Imp. weight of source factors; E*, Imp. weight of enabler; A*, Imp. weight of attributes, E1, E2, E3, E4, E5, ratings of five experts

During the analysis, CI and CR were evaluated to ensure consistency in experts' judgement and their values were found ⩽0.1, satisfying the requirement of consistency in experts' judgements.

4.3.2 Phase II: assessment of marketing-based flexibility attributes. In this phase, using multi-grade fuzzy scale, a decision-making group consisting of five members, rated flexibility attributes in the case firm. The rating of attributes was done with reference to their level of flexibility in implementation. As an example, attributes of enabler "DMT" were rated by five experts as follows:

$$R_{DMT} = \begin{bmatrix} 8 & 7 & 8 & 7 & 8 \\ 6 & 7 & 6 & 5 & 5 \\ 7 & 8 & 6 & 7 & 6 \\ 6 & 4 & 6 & 5 & 4 \end{bmatrix}$$

Similarly, rating for other marketing-based flexibility attributes were taken from experts (Table I).

4.3.3 Phase III: assessment of marketing-based flexibility using index method. The following steps were involved in the computation of marketing-based flexibility index of the firm.

Step 1: computation of index for marketing-based flexibility enablers. Index matrix corresponding to an enabler can be computed as follows:

$$I_E = \left[W_{ij} \times R_{ij}\right]$$

where I_E is the index matrix corresponding to a marketing-based flexibility enabler; W_{ij} the importance weight matrix of attributes of an enabler; and R_{ij} the assessment matrix of attributes of an enabler.

For example, assessment matrix and importance weight matrix corresponding to attributes of enabler "DMT" can be represented as follow:

$$R_{DMT} = \begin{bmatrix} I_{CAD} \\ I_{AMT} \\ I_{MF} \\ I_{AI} \end{bmatrix} \qquad W_{DMT} = \begin{bmatrix} W_{CAD} & W_{AMT} & W_{MF} & W_{AI} \end{bmatrix}$$

where I_{CAD}, I_{AMT}, I_{MF} and I_{AI} represent index matrices of attributes for enabler DMT as rated by experts in Phase II. Similarly, W_{CAD}, W_{AMT}, W_{MF} and W_{AI} represent importance weights of these attributes. Thus, index matrix corresponding to DMT is computed as follow:

$$\begin{aligned} I_{DMT} &= \left[W_{DMT} \times R_{DMT}\right] \\ &= \begin{bmatrix} 0.36 & 0.18 & 0.32 & 0.14 \end{bmatrix} \times \begin{bmatrix} 8 & 7 & 8 & 7 & 8 \\ 6 & 7 & 6 & 5 & 5 \\ 7 & 8 & 6 & 7 & 6 \\ 6 & 4 & 6 & 5 & 4 \end{bmatrix} \\ &= \begin{bmatrix} 7.04 & 6.90 & 6.72 & 6.36 & 6.26 \end{bmatrix} \end{aligned}$$

Similarly, index matrices for other marketing-based flexibility enablers were computed as follow:

$$I_{PIT} = [5.96 \quad 6.96 \quad 7.24 \quad 6.40 \quad 6.11]$$

$$I_{WIP} = [3.81 \quad 5.25 \quad 5.07 \quad 6.05 \quad 7.10]$$

$$I_{MIP} = [5.14 \quad 5.59 \quad 5.21 \quad 5.68 \quad 6.34]$$

$$I_{SDP} = [6.85 \quad 6.22 \quad 6.86 \quad 6.41 \quad 6.17]$$

$$I_{PPI} = [6.75 \quad 6.57 \quad 7.01 \quad 6.46 \quad 5.85]$$

$$I_{CI} = [8.11 \quad 8.69 \quad 8.51 \quad 7.20 \quad 6.82]$$

$$I_{MMI} = [7.39 \quad 5.61 \quad 6.80 \quad 6.33 \quad 5.14]$$

$$I_{PF} = [5.70 \quad 6.65 \quad 5.52 \quad 5.98 \quad 5.41]$$

$$I_{SF} = [4.97 \quad 5.45 \quad 5.63 \quad 5.89 \quad 5.49]$$

Step 2: computation of index for each source factor. Index matrix corresponding to a source factor can be calculated as follows:

$$I_{SF} = [W_i \times R_i]$$

where I_{SF} the index matrix of ith flexibility source factor; W_i the importance weight matrix of enablers for ith source factor; and R_i the assessment matrix for enablers for ith source factor.

The assessment matrix and importance weight matrix of source factor "TC" can be represented as follow:

$$R_{TC} = \begin{bmatrix} I_{DMT} \\ I_{PIT} \end{bmatrix} \qquad W_{TC} = [W_{DMT} \quad W_{PIT}]$$

where I_{DMT} and I_{PIT} are index matrices of enablers – "DMT" and "Planning and Integration Technology". Similarly, W_{DMT} and W_{PIT} represent importance weights of these enablers.

Thus, the index matrix of source factor "TC" was computed as follows:

$$I_{TC} = [W_{TC} \times R_{TC}] = [W_{DMT} \quad W_{PIT}] \times \begin{bmatrix} I_{DMT} \\ I_{PIT} \end{bmatrix}$$

$$= [0.67 \quad 0.33] \times \begin{bmatrix} 7.04 & 6.90 & 6.72 & 6.36 & 6.26 \\ 5.96 & 6.96 & 7.24 & 6.40 & 6.11 \end{bmatrix}$$

$$= [6.68 \quad 6.92 \quad 6.89 \quad 6.37 \quad 6.21]$$

Similarly, index matrices for other source factors were computed as follow:

$$I_{OIP} = \begin{bmatrix} 5.36 & 5.71 & 5.72 & 6.02 & 6.48 \end{bmatrix}$$

$$I_{IP} = \begin{bmatrix} 7.52 & 7.12 & 7.56 & 6.72 & 6.01 \end{bmatrix}$$

$$I_{LF} = \begin{bmatrix} 5.21 & 5.85 & 5.59 & 5.92 & 5.46 \end{bmatrix}$$

Step 3: computation of marketing-based flexibility assessment index. Marketing-based flexibility index matrix was computed as follows:

$$I = [W \times R]$$

where I is the marketing-based flexibility index matrix. $W = \begin{bmatrix} W_{TC} & W_{OIP} & W_{IP} & W_{LF} \end{bmatrix}$, i.e., importance weight matrix for source factors, namely, "TC", "Organisational Improvement Practices", "Integration Practices" and "Logistics Flexibility":

$$R = \begin{bmatrix} I_{TC} \\ I_{OIP} \\ I_{IP} \\ I_{LF} \end{bmatrix},$$

i.e., assessment matrix of source factors.

Thus, marketing-based flexibility index matrix of the firm is computed as follows:

$$I = [W \times R] = \begin{bmatrix} W_{TC} & W_{OIP} & W_{IP} & W_{LF} \end{bmatrix} \times \begin{bmatrix} I_{TC} \\ I_{OIP} \\ I_{IP} \\ I_{LF} \end{bmatrix}$$

$$= \begin{bmatrix} 0.20 & 0.29 & 0.16 & 0.35 \end{bmatrix} \times \begin{bmatrix} 6.68 & 6.92 & 6.89 & 6.37 & 6.21 \\ 5.36 & 5.71 & 5.72 & 6.02 & 6.48 \\ 7.52 & 7.12 & 7.56 & 6.72 & 6.01 \\ 5.21 & 5.85 & 5.59 & 5.92 & 5.46 \end{bmatrix}$$

$$= \begin{bmatrix} 5.92 & 6.23 & 6.20 & 6.17 & 5.99 \end{bmatrix}$$

Since, computation of marketing-based flexibility index matrix (I) involves judgement of five experts, therefore, the marketing-based flexibility index of the firm can be calculated as follow:

$$I = \frac{1}{n}\sum_{j=1}^{n=5} I_j \text{ Here, } n = \text{number of experts involved in the study}$$

$$= \frac{1}{5}(5.92 + 6.23 + 6.20 + 6.17 + 5.99) = 6.10$$

5. Discussion

The marketing flexibility index for the case firm X was found 6.10 and key concern areas for flexibility improvement were determined using comparative analysis of flexibility enablers (Figure 2).

5.1 Comparative analysis of enablers and gap analysis

The highest value of index was found for "customer integration" followed by "DMT", "planning and integration technology", "product/process technology integration", "supplier development practices" and "marketing and manufacturing integration". On the other hand, lowest value of index was observed for "workforce improvement practices" followed by "supply flexibility", "manufacturing improvement practices" and "purchasing flexibility".

The findings were discussed with experts involved in the study and possible causes of low value of indices were asked. One of the interesting findings of the study is that despite having high value of indices for some of the technological factors, the value of marketing-based flexibility index for the case firm was only 6.10. Contrary to the earlier studies, which suggest that different forms of AMTs enable flexibility in firms (Zhang *et al.*, 2006; Mishra *et al.*, 2014b), an average level of marketing-based flexibility index was mainly due to low indices for "workforce improvement practices" followed by "supply flexibility", "manufacturing improvement practices" and "purchasing flexibility". The lowest value of index for workforce improvement practices was due to "less participation of shop-floor workers in problem solving", "non-differential salary and compensation structure" and "less opportunity for workers to participate in broad range of tasks". On reflection, it was found that top down decision-making approach followed by the firm restricts the workers' participation in day-to-day problem-solving activities. Further, high ratio of contractual employees in firm restricts implementation of skill-based training and performance-based compensation and limits workers participation in decision making.

The low value indices for supply flexibility and purchasing flexibility were other concern areas for management. Experts expressed that absence of process visibility and lack of real time tracking created dysfunction in firms' supply chain, including long lead-time, excess inventory, and risk of obsolescence. Further, low level of supplier integration led to quality- and delivery-related problems. Initially, supply inflexibility was a major concern area that led to over-stocking of premium products and frequent stock-outs of fast selling products. Gradually, supplier development practices were employed to integrate suppliers at different level, however, significant efforts are still needed to increase its flexibility. The low value of purchasing flexibility index was attributed to factors, such as inadequate inbound transportation management, lack of alternative supply arrangement, heavy dependence on limited number of suppliers and lack of order visibility. Firm is yet to extensively employ

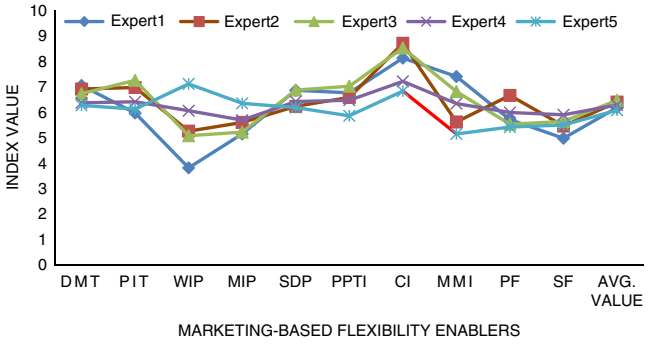

Figure 2. Graphical representation of indices

modularity and just in time supply to develop response supply chain. Due to low predictable quantity and timing of demand, firm is finding difficult to implement just-in-time strategy leading to significantly low inventory turn ratio. Similarly, low value of manufacturing improvement index was mainly due to improper implementation of preventive maintenance and just-in-time practices.

On a different note, case firm has strong customer integrative practices in place. Firm has a close customer integration with a robust mechanism to handle and prevent customer complaints. Sharing of customers' ratings and reviews, effective grievance handling and feedback management system led to continuous quality improvement. Several attempts have been made to update layout and improve material handling system to improve space utilisation and efficiency. Use of several latest technologies across operational functions and practices, such as job rotations and PDM software helped in developing flexibility.

5.2 Key concern areas

The set of recommendations proposed based on key concern areas are as follows:

(1) Exercise flexible working practices:
   - involve shop-floor workers in problem solving;
   - provide multi-skilled training and skill-based compensation practices; and
   - hire seasonal workers to deal with seasonal demand variations.

(2) Develop and implement high integration across supply chain:
   - involve suppliers in planning and goal setting activities; and
   - encourage collaborative practices among supply chain partners.

(3) Optimise inbound transportation in firm:
   - long-term agreement with carriers to safeguard against fuel price volatility; and
   - implement dynamic optimisation tools.

(4) Practise supplier development practices in firm:
   - share real time production information with suppliers;
   - synchronise raw materials supply with production scheduling; and
   - set annual performance expectations for suppliers.

6. Implications

From a theoretical standpoint, the study suggests the need to assess marketing-based flexibility so as to improve flexible planning in organisations. Despite being a widely researched area, the need of operations managers has not yet been met (Chuu, 2005). One of the fundamental questions that remains open and demands discussion is measurement of flexibility (Urtasun-Alonso *et al.*, 2014). Unlike majority of earlier studies that attempted either objectively or theoretically to assess flexibility (Beach *et al.*, 2000), this study proposes a hybrid approach that measures relative contribution of each source factor, enabler and attribute in flexibility development. Earlier studies reported that identifying flexibility source factors is difficult (Upton, 1995; Urtasun-Alonso *et al.*, 2014). This study extends knowledge about marketing-based flexibility by identifying new antecedents of marketing-based flexibility, such as purchasing flexibility and logistics flexibility. To the best of our knowledge, none of the earlier studies measured marketing-based flexibility with respect to its source factors, enablers and their attributes.

The findings of the study also have practical implications for firms. Since the level of flexibility is directly related to marketing planning, the proposed approach can assist in decision related to marketing planning. The study provides a list of enablers that practitioners should consider for the assessment of marketing-based flexibility in firms. The proposed hybrid approach helps practitioners to identify the level of flexibility in their organisation and thereby identify the weak areas for flexibility improvement.

7. Conclusion

The study proposes and demonstrates an application of a systematic and comprehensive flexibility assessment approach. The study gives a reliable and valid method, which combines both statistical and MCDM techniques, to measure current level of flexibility and identifies weak areas for flexibility improvement. The elements of assessment model have been derived from statistical technique using PCA, thereby reliability and validity of flexibility enablers and their associated attributes are well established. Use of AHP-multi-grade fuzzy methods to get the importance weight and assessment rating give an opportunity to incorporate multiple criteria and uncertainty elements in the assessment of flexibility.

7.1 Limitation and future research

The application of the proposed approach has been demonstrated using a single case example. For generalisation point of view, the application of the proposed approach can be investigated in a large number of firms from different industrial settings. The assessment model evaluates marketing-based flexibility at plant level. Therefore, in future, proposed approach can be extended to measurement of overall flexibility level of an organisation by including several other factors that influence marketing-based flexibility. The result of the study can also be compared using other MCDM and statistical methods.

References

Beach, R., Muhlemann, A.P., Price, D.H.R., Paterson, A. and Sharp, J.A. (2000), "A review of manufacturing flexibility", *European Journal of Operational Research*, Vol. 122 No. 1, pp. 41-57.

Boyle, T.A. (2006), "Towards best management practices for implementing manufacturing flexibility", *Journal of Manufacturing Technology Management*, Vol. 17 No. 1, pp. 6-21.

Chang, S.C., Lin, R.J., Chen, J.H. and Huang, L.H. (2005), "Manufacturing flexibility and manufacturing proactiveness: empirical evidence from the motherboard industry", *Industrial Management and Data Systems*, Vol. 105 No. 8, pp. 1115-1132.

Chang, S.C., Chen, R.H., Lin, R.J., Tien, S.W. and Sheu, C. (2006), "Supplier involvement and manufacturing flexibility", *Technovation*, Vol. 26 No. 10, pp. 1136-1146.

Chen, I.J., Calantone, R.J. and Chung, C.H. (1992), "The marketing-manufacturing interface and manufacturing flexibility", *Omega*, Vol. 20 No. 4, pp. 431-443.

Chuu, S.J. (2005), "Fuzzy multi-attribute decision-making for evaluating manufacturing flexibility", *Production Planning and Control*, Vol. 16 No. 3, pp. 323-335.

Dangayach, G.S. and Deshmukh, S.G. (2005), "Advanced manufacturing technology implementation: evidence from Indian small and medium enterprises (SMEs)", *Journal of Manufacturing Technology Management*, Vol. 16 No. 5, pp. 483-496.

Das, A. and Caprihan, R. (2008), "A rule-based fuzzy-logic approach for the measurement of manufacturing flexibility", *The International Journal of Advanced Manufacturing Technology*, Vol. 38 Nos 11-12, pp. 1098-1113.

Didonet, S., Simmons, G., Díaz-Villavicencio, G. and Palmer, M. (2012), "The relationship between small business market orientation and environmental uncertainty", *Marketing Intelligence & Planning*, Vol. 30 No. 7, pp. 757-779.

Filieri, R. (2015), "From market-driving to market-driven: an analysis of Benetton's strategy change and its implications for long-term performance", *Marketing Intelligence & Planning*, Vol. 33 No. 3, pp. 238-257.

Gerwin, D. (1993), "Manufacturing flexibility: a strategic perspective", *Management science*, Vol. 39 No. 4, pp. 395-410.

Gorsuch, R.L. (1997), "Exploratory factor analysis: its role in item analysis", *Journal of Personality Assessment*, Vol. 68 No. 3, pp. 532-560.

Gupta, Y.P. and Somers, T.M. (1992), "The measurement of manufacturing flexibility", *European Journal of Operational Research*, Vol. 60 No. 2, pp. 166-182.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2010), *Multivariate Data Analysis: A Global Perspective*, Pearson, Upper Saddle River, NJ.

Hallgren, M. and Olhager, J. (2009), "Lean and agile manufacturing: external and internal drivers and performance outcomes", *International Journal of Operations and Production Management*, Vol. 29 No. 10, pp. 976-999.

Ishizaka, A. and Labib, A. (2011), "Review of the main developments in the analytic hierarchy process", *Expert Systems With Applications*, Vol. 38 No. 11, pp. 14336-14345.

Kathuria, R. and Partovi, F.Y. (1999), "Work force management practices for manufacturing flexibility", *Journal of Operations Management*, Vol. 18 No. 1, pp. 21-39.

Koste, L.L., Malhotra, M.K. and Sharma, S. (2004), "Measuring dimensions of manufacturing flexibility", *Journal of Operations Management*, Vol. 22 No. 2, pp. 171-196.

Logman, M. (2008), "Contextual intelligence and flexibility: understanding today's marketing environment", *Marketing Intelligence & Planning*, Vol. 26 No. 5, pp. 508-520.

MacCallum, R.C., Widaman, K.F., Zhang, S. and Hong, S. (1999), "Sample size in factor analysis", *Psychological Methods*, Vol. 4 No. 1, pp. 84-99.

Malhotra, M.K. and Sharma, S. (2008), "Measurement equivalence using generalizability theory: an examination of manufacturing flexibility dimensions", *Decision Sciences*, Vol. 39 No. 4, pp. 643-669.

Mishra, R. (2016), "A comparative evaluation of manufacturing flexibility adoption in SMEs and large firms in India", *Journal of Manufacturing Technology Management*, Vol. 27 No. 5, pp. 730-762.

Mishra, R., Pundir, A.K. and Ganapathy, L. (2014a), "Assessment of manufacturing flexibility: a review of research and conceptual framework", *Management Research Review*, Vol. 37 No. 8, pp. 750-776.

Mishra, R., Pundir, A.K. and Ganapathy, L. (2014b), "Manufacturing flexibility research: a review of literature and agenda for future research", *Global Journal of Flexible Systems Management*, Vol. 15 No. 2, pp. 101-112.

Mishra, R., Pundir, A.K. and Ganapathy, L. (2017), "Evaluation and prioritisation of manufacturing flexibility alternatives using integrated AHP and TOPSIS method: evidence from a fashion apparel firm", *Benchmarking: An International Journal*, Vol. 24 No. 5, pp. 1437-1465.

Narain, R., Yadav, R.C., Sarkis, J. and Cordeiro, J.J. (2000), "The strategic implications of flexibility in manufacturing systems", *International Journal of Agile Management Systems*, Vol. 2 No. 3, pp. 202-213.

Oke, A. (2005), "A framework for analysing manufacturing flexibility", *International Journal of Operations and Production Management*, Vol. 25 No. 10, pp. 973-996.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, pp. 879-903.

Poolton, J., Ismail, H.S., Reid, I.R. and Arokiam, I.C. (2006), "Agile marketing for the manufacturing-based SME", *Marketing Intelligence & Planning*, Vol. 24 No. 7, pp. 681-693.

Saaty, T.L. (1980), *The Analytic Hierarchy Process*, McGraw-Hill, New York, NY.

Sipahi, S. and Timor, M. (2010), "The analytic hierarchy process and analytic network process: an overview of applications", *Management Decision*, Vol. 48 No. 5, pp. 775-808.

Subramanian, N. and Ramanathan, R. (2012), "A review of applications of analytic hierarchy process in operations management", *International Journal of Production Economics*, Vol. 138 No. 2, pp. 215-241.

Swink, M., Narasimhan, R. and Wang, C. (2007), "Managing beyond the factory walls: effects of four types of strategic integration on manufacturing plant performance", *Journal of Operations Management*, Vol. 25 No. 1, pp. 148-164.

Thakur, L.S. and Jain, V.K. (2008), "Advanced manufacturing techniques and information technology adoption in India: a current perspective and some comparisons", *The International Journal of Advanced Manufacturing Technology*, Vol. 36 No. 5, pp. 618-631.

Upton, D.M. (1994), "The management of manufacturing flexibility", *California Management Review*, Vol. 36 No. 2, pp. 72-89.

Upton, D.M. (1995), "Flexibility as process mobility: the management of plant capabilities for quick response manufacturing", *Journal of Operations Management*, Vol. 12 No. 3, pp. 205-224.

Urtasun-Alonso, A., Larraza-Kintana, M., García-Olaverri, C. and Huerta-Arribas, E. (2014), "Manufacturing flexibility and advanced human resource management practices", *Production Planning and Control*, Vol. 25 No. 4, pp. 303-317.

Vokurka, R.J. and O'Leary-Kelly, S.W. (2000), "A review of empirical research on manufacturing flexibility", *Journal of Operations Management*, Vol. 18 No. 4, pp. 485-501.

Wagner, S.M. and Krause, D.R. (2009), "Supplier development: communication approaches, activities and goals", *International Journal of Production Research*, Vol. 47 No. 12, pp. 3161-3177.

Wang, R.C. and Chuu, S.J. (2004), "Group decision-making using a fuzzy linguistic approach for evaluating the flexibility in a manufacturing system", *European Journal of Operational Research*, Vol. 154 No. 3, pp. 563-572.

Yang, S.L. and Li, T.F. (2002), "Agility evaluation of mass customization product manufacturing", *Journal of Materials Processing Technology*, Vol. 129 No. 1, pp. 640-644.

Zhang, Q., Vonderembse, M.A. and Cao, M. (2006), "Achieving flexible manufacturing competence: the roles of advanced manufacturing technology and operations improvement practices", *International Journal of Operations and Production Management*, Vol. 26 No. 6, pp. 580-599.

Zhang, Q., Vonderembse, M.A. and Lim, J.S. (2005), "Logistics flexibility and its impact on customer satisfaction", *The International Journal of Logistics Management*, Vol. 16 No. 1, pp. 71-95.

Further reading

Mishra, R., Pundir, A.K. and Ganapathy, L. (2016), "Conceptualizing sources, key concerns and critical factors for manufacturing flexibility adoption: an exploratory study in Indian manufacturing firms", *Journal of Manufacturing Technology Management*, Vol. 27 No. 3, pp. 379-407.

Corresponding author
Ruchi Mishra can be contacted at: ruchi461@gmail.com