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ORIGINAL ARTICLE

A hybrid MCDM approach for agile concept selection using fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS

S. Vinodh[1] · **T. S. Sai Balagi**[1] · **Adithya Patil**[1]

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Abstract Manufacturing organisations are witnessing a transformation in the manufacturing paradigm due to the increasing competition. Agile manufacturing (AM) is an operations concept that is intended to improve the competitiveness of firms. When market conditions are unfavourable, a firm needs to stay competitive in order to function well and remain in good health. In such situations, it becomes essential that an organisation optimises its manufacturing processes so that it would adapt to changes in an unpredictable market scenario and remain competitive. AM principles enable an organisation to sustain in the competitive market scenario. Concept selection for an AM system is a typical multi-criteria decision making (MCDM) problem. In order to enhance the effectiveness of concept selection, a unique combination of fuzzy decision making trial and evaluation laboratory (DEMATEL), fuzzy analytical network process (ANP) and fuzzy technique for order preference by similarity to ideal solution (TOPSIS) was used in the study. The study is aimed at selecting the best concept design of an automobile component. The selected design was subjected to implementation in the case organisation.

Keywords Agility · Concept selection · Multi-criteria decision making · DEMATEL · ANP · TOPSIS · Fuzzy logic

✉ S. Vinodh
vinodh_sekar82@yahoo.com

[1] Department of Production Engineering, National Institute of Technology, Tiruchirappalli 620 015, Tamil Nadu, India

Notations

$\tilde{A}$ Fuzzy direct-relation matrix
$\tilde{N}$ Normalised direct-relation matrix
$\tilde{T}$ Total-relation matrix
$\widetilde{A}'$ Fuzzy pairwise comparison matrix
$\tilde{w}$ Fuzzy relative importance weights
$\tilde{D}$ Decision matrix between the alternatives and the criteria

1 Introduction

Agile manufacturing (AM) enables manufacturing organisations to survive in the competitive environment of continuous and unanticipated changes. Concept selection in the context of AM is a typical multi-criteria decision making (MCDM) problem as it considers several agile criteria. Hence, an appropriate MCDM method needs to be applied. Since a single MCDM method cannot provide an effective solution, a hybrid approach was used. Using analytical network process (ANP), relationships between agility factors and dependence in feedback can be dealt in an effective manner. Also, decision making trial and evaluation laboratory (DEMATEL) method was used to generate mutual relationships of interdependencies within the agile criteria and also the strength of interdependence. To select the best alternative, technique for order preference by similarity to ideal solution (TOPSIS) was used. Fuzzy logic was used in evaluations that take into account the uncertainty that exists among the agility factors. This was done keeping in mind the impreciseness that often accompanies human judgement. A case study was conducted in an instrument panel manufacturing organisation. The selected concept design was subjected to implementation in the case organisation.

2 Literature review

2.1 Review on agility

Vinodh et al. [17] used an axiomatic model of an agile production system to help provide directives to refine the design process of an Indian modular switch manufacturing company. Vinodh [17] presented a research on how to improve the agility and sustainability of rotary switch knob. The design was analysed using Sustainability Xpress software module, and it was found that the environmental impact of the design was low. This study also pointed an increase in agility. Vinodh et al. [19] applied a scoring model to evaluate the agility of a firm before and after the implementation of total agile design system (TADS). An increase of 10 % had been reported in the firm after the implementation of TADS. The agility evaluation of large-scale customised product manufacturing was performed using multi-grade fuzzy assessment method by Yang et al. [20]. An evaluation system for mass customised product manufacturing agility was established in their study. After the evaluation system was applied to the case organisation, the organisation was found to be agile. Swafford et al. [15] explained how important the use of information technology (IT) is in improving flexibility and, therefore, the agility of a supply chain. Confirmatory factor analysis (CFA) and structural equation modelling (SEM) were used to obtain the results. The study showed how IT integration, supply chain flexibility, supply chain agility and competitive business performance were interrelated and dependent on each other and on how agility could be achieved by investing in IT. Inman et al. [8] proposed that Just-In-Time (JIT) manufacturing (JIT production and JIT purchasing) and agility are interrelated. Major US companies were surveyed and analysed. Necessary data was collected and processed using the SEM methodology. Iivari et al. [7] presented a study that is focussed on the relationship between organisational culture and the deployment of agile methods. Potential research areas in this field were also identified. Ngai et al. [12] conducted a study on how a firm's performance was dependent on the relation between supply chain competence and supply chain agility. The findings of their *exploratory research* emphasise on making a distinction between how supply chain agility and supply chain management differ from each other and on how they impact a firm's performance. The problem of configuring manufacturing supply chains was attempted by Constantino et al. [4]. A method for the management of supply chains at the strategic level to allow enhancement of manufacturing supply chain agility with regard to reconfiguration ability was explained as a part of their presentation.

2.2 Review on the application of MCDM methods

An analytic hierarchy process (AHP)-TOPSIS combination was used by Lin et al. [9] to help designers in characterising the requirements of customers and design products accordingly, and assist in the evaluation of the final design solution. The outcomes of the research showed the effectiveness of the method in helping designers select essential data and determine the important design objectives. AHP and fuzzy TOPSIS methods were combined by Amiri [2], and this hybrid methodology was used in the selection of a project for the National Iranian Oil Company. The paper put forward a simple approach to evaluate project alternatives. The result was a set of rankings corresponding to each oil field. The rankings were used to select the best oil field. Dağdeviren et al. [5] used AHP and TOPSIS methods "under a fuzzy environment" as an effective selection tool for the selection of appropriate weapons. The paper explained the use of the AHP-TOPSIS as a selection tool. Macharis et al. [10] suggested ways to strengthen preference ranking organization method for enrichment of evaluation (PROMETHEE), with ideas from AHP. A detailed analysis of both methods was conducted by the authors, which finally concluded with a detailed comparison of both methods. The numerous advantages and limitations of both methods were pointed in detail. Alp et al. [1] used a combination of fuzzy AHP and PROMETHEE to identify a suitable location for a bus garage for an Istanbul-based transport company. Vinodh et al. [19] applied fuzzy ANP for the selection of an agile concept for a manufacturing organisation. In this study, the authors stressed the importance of selecting the right concept design to improve the agility of the organisation. Agile concept selection was explained as a part of the TADS. Ozdemir et al. [13] employed ANP as a tool to select a suitable aircraft for purchase by Turkish Airlines. Necessary criteria were decided upon, and an aircraft model was selected for purchase. Their findings were observed by Turkish Airlines. The report elucidated the use of ANP as a selection (decision-making) tool. A combination of fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS methods was used by Büyüközkan et al. [3] in the selection of a green supplier. Diagrams illustrating the nature of dependencies between enablers and criteria were used to depict the structuring of the solution to the problem, and the use of the three methods was explained in a clear manner. The weights of the criteria that influenced the final choices (alternatives) were determined using DEMATEL and ANP, and based on the so-obtained weights, the alternatives were evaluated using TOPSIS. Viglas et al. [16] proposed a model that combined the balanced scorecard (BSC) methodology and ANP for assisting an IT company support investment decisions. In this paper, the drawbacks of using traditional methods of investment appraisal were highlighted. However, it was pointed out that financial indices were important for assessing the value of IT investment. This problem was approached using MCDM methods that take into consideration factors that conventional investment appraisal methods did not. Monavvarian et al. [11] used ANP and TOPSIS methods to help the Pars Tire Company to select knowledge management strategies. In this paper, the importance of knowledge management for the success of a firm was stressed. Because of the complex nature of the criteria involved, and the complex nature of the interdependencies among the criteria, ANP was chosen as an MCDM modelling tool. With the weights of the criteria generated using this model, the knowledge management strategies were ranked using TOPSIS, and a suitable strategy was selected. Fouladgar et al. [6] used a combination of SWOT (strength, weakness, opportunities and threats), ANP and VlseKriterijumskaOptimizacija I KompromisnoResenje (VIKOR) to evaluate the strategies of the Iranian Mining Sector. The criteria used for ANP were determined from SWOT analysis of the problem. This was done because of the exhaustive nature of the factors that can affect the SWOT analysis. ANP was applied for determining the weights of the SWOT factors. Strategies were ranked using the VIKOR technique.

3 Research gap

The use of MCDM methods in the context of AM is an approach that has not been attempted before. To achieve agility, it is essential that the products designed by a manufacturing organisation are agile in nature, because the core of agility lies in the selection of agile concept designs. The selection of an agile concept design is complicated in nature, because of the large number of factors and criteria involved. To deal with this complex nature of the problem, an MCDM method is applied. In this case study, integrated MCDM methods are used to find the most agile concept design. Thus, the research gap has been filled.

4 Methodology

The methodology used in this case study is a combination of DEMATEL, ANP and TOPSIS methods. The reason behind the selection of this combination of established methods in the selection of an agile concept design is that an approach of this nature has never been attempted for agile concept selection. This makes the approach unique and distinctive. An important purpose of this hybrid model is that it eliminates or, at least, reduces the possibilities of obtaining results that may be unscientific and arbitrary, and with the use of a fuzzy approach, the precision of the results is further enhanced. This approach was divided into three major segments. The first segment considers the dependencies that a set of criteria falling under an enabler have with each other. In this segment, fuzzy DEMATEL is used to assess the criterion weightage pertaining to each enabler with respect to other, with reference to other criteria considered at a time. The second segment takes into account as to how an enabler (rather, the criteria under an enabler) depends on the other enablers (again, criteria under other enablers) towards contribution to the goal and on how important an enabler is towards achieving the goal, which, in this case study, is selecting the most suitable agile concept design. Fuzzy ANP is used to model this segment, where the weights of the chosen criteria with respect to other criteria, taken one at a time, are computed. The third segment takes into account the relationship between the chosen criteria and available alternatives. Using TOPSIS and the results obtained from the previous segments, a set of rankings is obtained, and from these rankings, the most suitable concept design with regard to the chosen criteria is obtained (Fig. 1).

5 Case study

An Indian automotive plastics component manufacturing organisation located in Bangalore, India, was subjected to the case study. Members from various departments were selected and a cross functional team (CFT) was formed. The members of the so-formed CFT are the decision-makers. Inputs were gathered from the decision-makers. The present study forms the module of a major research project on AM in the organisation. At one point of time, the decision-makers felt the need to explore the concept design of an instrument panel in a more detailed manner.

6 Criteria

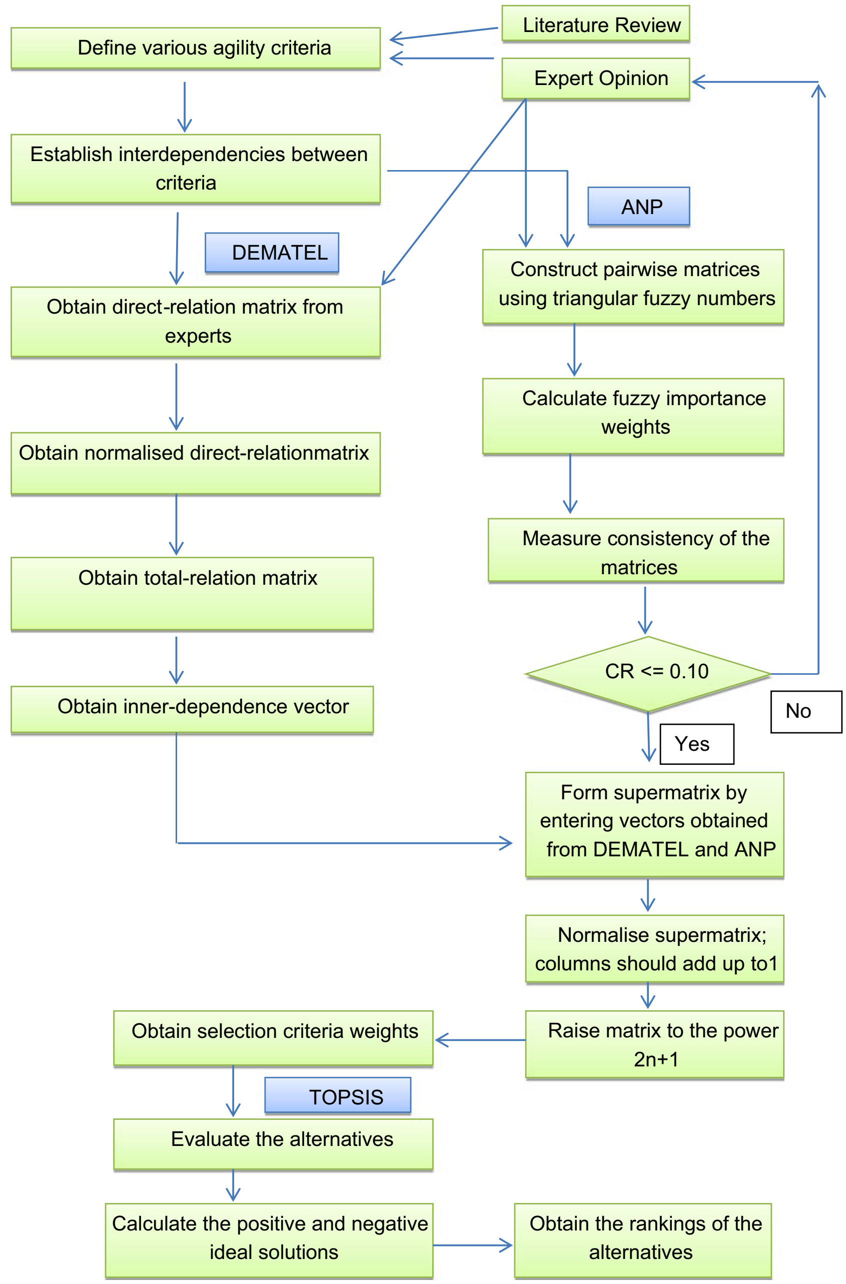
Agile criteria considered in the study include the following [18]: customer response adoption, nature of management, agile customisation, resource optimisation, employee involvement, employee status, product service, product methodology, concurrent processing, IT integration, advances in design, team working, business support systems, devolution of authority, organisational structure, design improvement, product life cycle, manufacturing setups, creativity, automation type, manufacturing planning, change in business and technical processes, outsourcing, cost management, time management, collaborative relationships, status of quality, status of productivity, flexible business practices and knowledge management (Fig. 2)

7 An overview of the methodologies used in this case study

7.1 DEMATEL

DEMATEL, standing for DEcision MAking Trial and Evaluation Laboratory, is a practical and effective method useful for

Fig. 1 Methodology



picturing complex causal relationships. In other words, this method is valuable in modelling of what are commonly known as *cause-effect* relationships.

7.2 ANP

ANP stands for analytical network process, a decision framework that takes into consideration the interdependencies (not necessarily hierarchical) that may exist among elements in the framework. Because dependencies of all kinds (and not just hierarchical) are considered, the results from ANP framework can be construed to be accurate and scientific (Fig. 3).

7.3 TOPSIS

TOPSIS stands for technique for order preference by similarity to ideal solution. The principle of this method is that the chosen alternative should be as close to the positive ideal solution as possible and as far away from the negative ideal solution as possible. The ideal solution is formed as a composite of the best performance values exhibited in the framework by each alternative for each attribute. The negative ideal solution is a composite of the worst performance values. Proximity to each of points is calculated in terms of Euclidean distance.

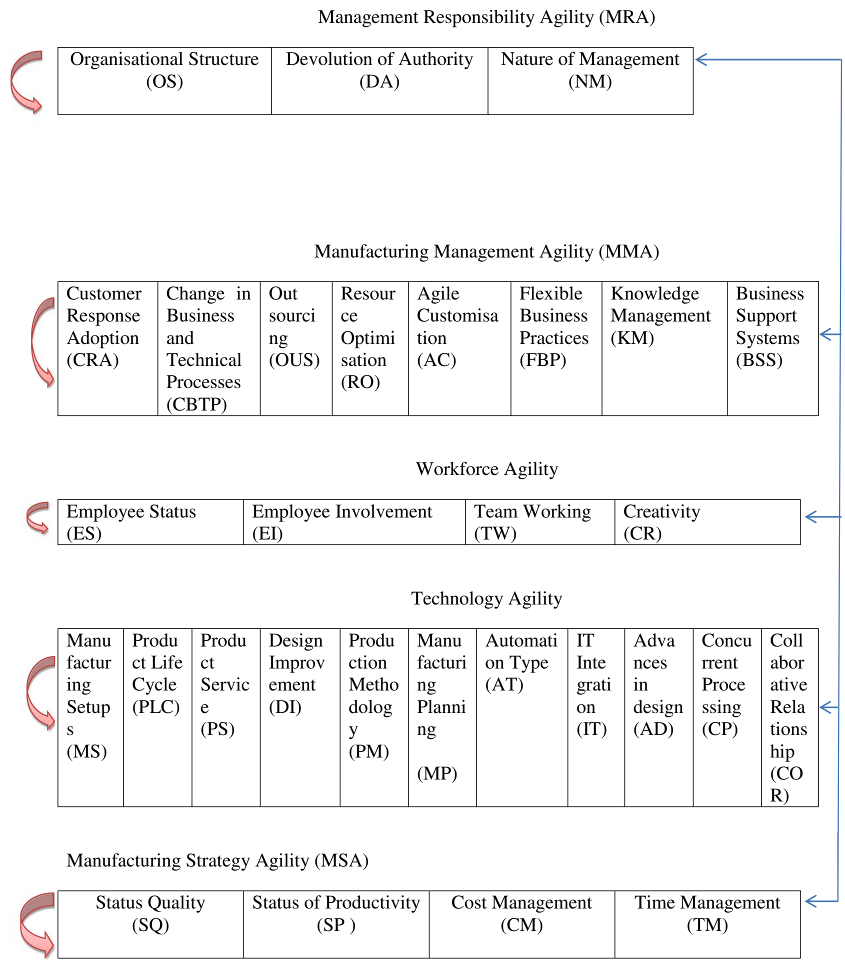


Fig. 2 Determination of the nature of dependencies

8 Steps involved in the application of the three methods

Judgements made by a human being often tend to be imprecise. A linguistic scale has been adopted keeping in mind the difficulties inherent in the quantification of complex systems that are not very easy to define. Adopted linguistic scale will aid the decision-maker in his assessment by providing for a certain degree of imprecision or, better, fuzziness. The linguistic scale and the corresponding fuzzy scale that have been employed for this case study are as given in Table 1 (Büyüközkan et al. [3]):

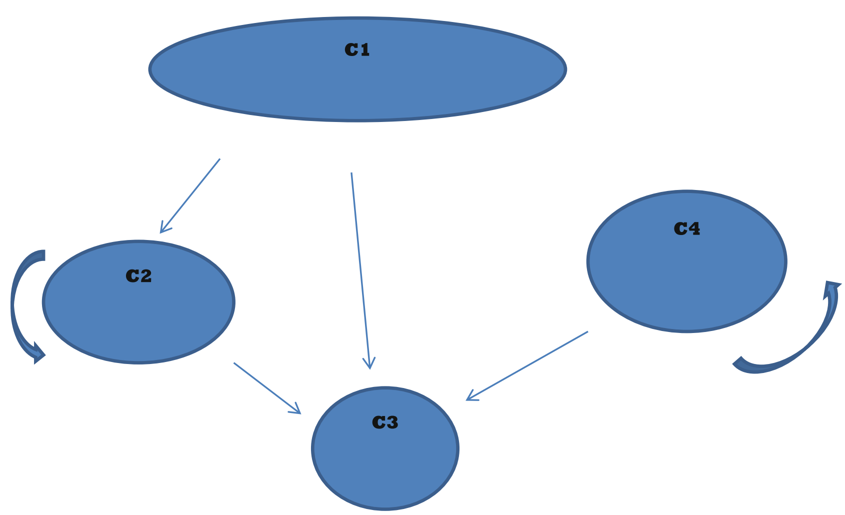


Fig. 3 A network

Table 1 Linguistic scale and the corresponding fuzzy scale

Linguistic scale	Abbreviation	Corresponding fuzzy scale
None	N	(0,0,1)
Very low	VL	(0,0.1,0.2)
Low	L	(0.1,0.2,0.3)
Fairly low	FL	(0.2,0.3,0.4)
More or less low	ML	(0.3,0.4,0.5)
Medium	M	(0.4,0.5,0.6)
More or less good	MG	(0.5,0.6,0.7)
Fairly good	FG	(0.6,0.7,0.8)
Good	G	(0.7,0.8,0.9)
Very good	VG	(0.8,0.9,1)
Excellent	E	(0.9,1,1)

8.1 Computational steps in fuzzy DEMATEL

(i) Causal relations between the criteria falling under an enabler are established. The decision-makers make sets of pairwise comparisons between criteria regarding the influence a criterion has over another criterion. This is written in the form of an $n \times n$ fuzzy matrix $\tilde{A}$ where fuzzy element $\tilde{a}_{ij}=l'_{ij},m'_{ij}\mu'_{ij}$ represents the relation between criterion i and criterion j. This matrix is called the *fuzzy direct-relation matrix* (Table 2).

(ii) In this step, the normalised direct-relation matrix is obtained. The normalised direct-relation matrix is obtained as

$$\tilde{N} = x\ \tilde{A} \quad (1)$$

where $\tilde{N}$ =normalised direct-relation matrix

$$k = {}^{1}\Big/_{\max_{1 \le i \le n} \sum_{j=1}^{n} u_{ij}} \ldots \quad (2)$$

$\tilde{A}$=fuzzy direct-relation matrix obtained from step (i) (Table 3)

(iii) The total-relation matrix is obtained in this step. The steps followed to obtain the total-relation matrix are explained as follows:

Table 2 Fuzzy direct-relation matrix

	OS	DA	NM
OS	*	FG	VG
DA	G	*	G
NM	G	G	*
	OS	DA	NM
OS	*	(0.6,0.7,0.8)	(0.8,0.9,1)
DA	(0.6,0.7,0.8)	*	(0.7,0.8,0.9)
NM	(0.7,0.8,0.9)	(0.7,0.8,0.9)	*

* Represents that there exists no relation between the dependencies

Table 3 Normalised direct-relation matrix

	OS	DA	NM
OS	*	(0.33,0.38,0.44)	(0.44,0.50,0.55)
DA	(0.33,0.38,0.44)	*	(0.38,0.44,0.50)
NM	(0.38,0.44,0.50)	(0.38,0.44,0.50)	*

* Represents that there exists no relation between the dependencies

Let $\tilde{n}_{ij}=l'_{ij},m'_{ij}\mu'_{ij}$ represent the elements of the normalised direct-relation matrix. The matrix $\tilde{N}$ broken down into three matrices N_1, N_2 and N_3 are as shown below.

$$N_1 = \begin{pmatrix} 0 & l_{12} & \cdots & l_{1n} \\ l_{21} & 0 & \cdots & l_{2n} \\ \vdots & \ddots & \cdots & \vdots \\ l_{n1} & l_{n2} & & 0 \end{pmatrix}$$

$$N_2 = \begin{pmatrix} 0 & m_{12} & \cdots & m_{1n} \\ m_{21} & 0 & \cdots & m_{2n} \\ \vdots & \ddots & \cdots & \vdots \\ m_{n1} & m_{n2} & & 0 \end{pmatrix}$$

$$N_3 = \begin{pmatrix} 0 & n_{12} & \cdots & n_{1n} \\ n_{21} & 0 & \cdots & n_{2n} \\ \vdots & \ddots & \cdots & \vdots \\ n_{n1} & n_{n2} & & 0 \end{pmatrix}$$

Now, the total-relation matrix, $\tilde{T}$, can be obtained as

$$\tilde{T} = \tilde{N}\left(I - \tilde{N}\right)^{-1} \ldots \quad (3)$$

If we take each term of the fuzzy matrix $\tilde{T}$ as $\tilde{t}_{ij} = l'_{ij}, m'_{ij}\mu'_{ij}$, then

$$l'_{ij} = N_1(I - N_1)^{-1},\ m'_{ij} = N_2(I - N_2)^{-1},\ n'_{ij} = N_3(I - N_3)^{-1} \ldots \quad (4)$$

where I is the identity matrix.

(iv) In this step, the inner-dependence matrix is obtained. This is done by defuzzifying the total-relation matrix obtained in the previous step and normalising it in such a way that the columns of the matrix so obtained add up to 1. This weighted matrix will be a part of the supermatrix. If $\tilde{t}_{ij} = \left(l'_{ij},\ m'_{ij}, u'_{ij}\right)$ is taken as an element of the total-relation matrix, then defuzzification is performed as (Table 4)

Table 4 Inner-dependence matrix

	OS	DA	NM
OS	0.333	0.339	0.340
DA	0.326	0.320	0.326
NM	0.339	0.339	0.333

$$F\left(\tilde{t}_{ij}\right) = \frac{1}{2}\int_{0}^{1}\left(\inf\tilde{t}_{ij}^{\ \propto} + \sup\tilde{t}_{ij}^{\ \propto}\right) d\propto \ldots \quad (5)$$

(v) In this manner, defuzzified and weighted total-relation matrices are computed and are inserted into the supermatrix.

8.2 Computational steps in fuzzy ANP

(i) As mentioned earlier, ANP is used to take into account the relationships between the criteria falling under the chosen enablers.
(ii) Making use of the same set of triangular fuzzy numbers, pairwise comparisons are made between the criteria belonging to enablers that have a dependency over each other. Let such a comparison matrix be called $\tilde{A}'$ (Table 5).
(iii) When the comparison matrix is obtained, its relative importance weights are calculated based on the logarithmic least squares method.

$$\text{If } \tilde{w}_k = \left(w_k^l, w_k^m, w_k^u\right),\ w_k^s = \frac{\left(\Pi_{i=1}^{n} a_{kj}^{s}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\Pi_{i=1}^{n} a_{ij}^{m}\right)^{\frac{1}{n}}},\ s\in\{l,m,u\}\ldots \quad (6)$$

(iv) The consistency ratios for each of the matrices and the overall inconsistency are computed. The consistency ratios are used to evaluate the consistency and should be less than 0.10. The ratios were calculated for the mean values of the fuzzy numbers. Because fuzzy numbers allow a certain degree of flexibility in human judgements, a certain degree of inconsistency is considered acceptable.
(v) Defuzzify the matrix so obtained using the same method as in the computations in DEMATEL. Thus, the weights are obtained. These weights are then inserted into the supermatrix (Table 6).

Table 5 Comparison matrix

MP	SQ	SP	CM	TM
SQ	1	G	VG	VG
SP		1	G	G
CM			1	FG
TM				1
MP	SQ	SP	CM	TM
SQ	(1,1,1)	(0.7,0.8,0.9)	(0.8,0.9,1)	(0.8,0.9,1)
SP		(1,1,1)	(0.7,0.8,0.9)	(0.7,0.8,0.9)
CM			(1,1,1)	(0.6,0.7,0.8)
TM				(1,1,1)

Table 6 Weights of MSA with respect to MP in TA, obtained using ANP

MP	Weights
SQ	0.2485
SP	0.2486
CM	0.2485
TM	0.2655

A supermatrix can be simply understood as a matrix of matrices, where the relationship involving entities that are dependent on each other is represented on a more *global* scale.

By placing the weight vectors obtained in DEMATEL and ANP in their respective positions in the supermatrix, we get the initial supermatrix. In the supermatrix, the interaction of each entity with the other entities is represented (Table 7).

After the initial supermatrix is obtained, the columns are normalised in such a way that the values in each column add up to 1. The matrix so obtained is raised to the power 25. The matrix obtained after normalising and raising to the power 25 is shown in Table 8.

8.3 Computational steps using TOPSIS

(i) A fuzzy decision matrix is obtained between the alternatives and the criteria.

If there are p alternatives and q criteria, the decision matrix would look like this:

$$\tilde{D} = \begin{pmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1q} \\ \vdots & \vdots & & \vdots \\ \tilde{x}_{p1} & \cdots & & \tilde{x}_{pq} \end{pmatrix}$$

Table 7 Initial supermatrix

	GOAL	OS	DA	NM	…	CM	TM
GOAL	0	0	0	0	…	0	0
OS	0.0647	0.3338	0.3396	0.34	…	0.3174	0.3312
DA	0.0647	0.3265	0.3207	0.3265	…	0.3174	0.3252
NM	0.0647	0.3396	0.3396	0.3333	…	0.3419	0.3312
⋮	⋮	⋮	⋮	⋮	…	⋮	0.1238
CM	0.0518	0.0526	0.2548	0.2543	…	0.25	0.25
TM	0.0518	0.2577	0.267	0.2621	…	0.25	0.25

Table 8 Weighted supermatrix

	GOAL	OS	DA	NM	…	CM	TM
GOAL	0	0	0	0	…	0	0
OS	0.0651	0.0651	0.0651	0.0651	…	0.0651	0.0651
DA	0.0652	0.0652	0.0652	0.0652	…	0.0652	0.0652
NM	0.0673	0.0673	0.0673	0.0673	…	0.0673	0.0673
⋮	⋮	⋮	⋮	⋮	…	⋮	⋮
CM	0.0501	0.0501	0.0501	0.0501	…	0.0501	
TM	0.0518	0.0518	0.0518	0.0518	…	0.0518	0.0518

(ii) The decision matrix is normalised. If the normalised decision matrix is represented as

$$\tilde{R} = \left[\tilde{v}_{ij}\right]_{m\times n}, \quad i = 1,2,3....$$
$$j = 1,2,3..., \text{ then } \left[\tilde{r}_{ij}\right]_{m\times n} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+}\right),$$
$$\text{where } C_j^+ = \max_i C_{ij}... \tag{7}$$

(iii) A linear scale transformation [3] is used to sidestep the complex normalisation method followed in standard TOPSIS. As a result of employing this, the normalised matrix remains the same because $\max_i C_{ij}=1$.

(iv) The weighted decision matrix is computed. If $\tilde{v}=[\tilde{v}_{ij}]_{m\times n}$ is the weighted decision matrix, then

$$\left[\tilde{v}_{ij}\right]_{m\times n} = \tilde{r}_{ij} \times \tilde{w}_{ij}... \tag{8}$$

The $\tilde{w}_{ij}$ vector is the column of weights under the "GOAL" column in the supermatrix.

(v) Distances of the alternatives from the positive and negative ideal points are calculated. Since the triangular fuzzy numbers used here are in the range [0,1], the positive and negative ideal reference points are taken as

$$A^+ = \left\{\tilde{v}_1^+, \ \tilde{v}_2^+, ... \ \tilde{v}_n^+\right\}, A^- = \left\{\tilde{v}_1^-, \ \tilde{v}_2^-, ... \ \tilde{v}_n^-\right\}, \text{ where } \tilde{v}_i^+ = (1,1,1) \text{ and } \tilde{v}_i^- = (0,0,0) \tag{9}$$

$$d_i^+ = \sum_{j=i}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_i^+\right) i =, 1,2,3..., mj = 1,2,3..., n...$$

$$d_i^- = \sum_{j=i}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_i^+\right) i =, 1,2,3..., mj = 1,2,3..., n... \tag{10}$$

The positive and negative distances can be seen Table 9.

(vi) The values of $\frac{d^-}{d^-+d^+}$ corresponding to each of the alternatives are calculated. Based on the magnitude of these values, the alternatives are ranked. The alternative with the highest rank is considered as the most suitable alternative with the chosen criteria (Table 10).

9 Results and discussions

The results obtained from DEMATEL and TOPSIS are placed in the supermatrix in their respective positions. From the results obtained in the weighted supermatrix, it can be seen that a greater emphasis is placed on the enabler management responsibility agility. It can be seen that importance is given to the nature of management and to the devolution of authority. This happens to be true because, in most cases, it is the management that takes crucial decisions. In critical situations, decisions taken by the management can make or break a

Table 9 Positive-negative distances from ideal points

	Positive distances							Negative distances						
	OS	DA	NM	…	CM	TM	d+	OS	DA	NM	…	CM	TM	d−
A1	0.948	0.941	0.933	…	0.955	0.948	29.12	0.052	0.059	0.067	…	0.045	0.052	0.8876
A2	0.941	0.948	0.939	…	0.96	0.953	29.152	0.059	0.052	0.061	…	0.04	0.047	0.847
A3	0.954	0.948	0.953	…	0.96	0.953	29.224	0.046	0.052	0.047	…	0.04	0.047	0.78
A4	0.954	0.961	0.96	…	0.965	0.959	29.311	0.046	0.039	0.04	…	0.035	0.041	0.687
A5	0.948	0.961	0.96	…	0.965	0.959	29.306	0.046	0.039	0.04	…	0.035	0.041	0.688

Table 10 Final performance indices

A1	0.02958
A2	0.02823
A3	0.02599
A4	0.022902
A5	0.022938

company. So, quite understandably, the agility of a company is directly influenced by the nature of its management. Another aspect that has been stressed upon, in the obtained results, is the importance of devolving authority. If quick decisions can be made without having to travel too much up the hierarchal ladder, changes can be brought about in an efficient manner, and this increases the adaptability of a firm in bad times. The results obtained in the weighted supermatrix also underscore the importance of the enabler manufacturing strategy agility. Cost management and time management are, quite obviously, fundamental to the well-being of a company. Cost-cutting and other forms of austerity measures need to be adopted to curb wasteful expenditure—an idea central to achieving agility. While ensuring all of the above, the productivity of the employees and the quality of the products have to be kept in mind, and decisions must be taken accordingly. It is important that the quality of products should not be compromised.

From the third segment of the computations, the performance indices of the alternatives were arrived at. Based on the magnitude of the performance indices, the alternatives were ranked. The order of suitability, as understood from the performance indices, is A1, A2, A5, A4 and A3. From the obtained results, it can be seen that alternative A1 is the most suitable alternative. This concept design was subjected to implementation in the case organisation.

10 Conclusion

The study utilises a novel hybrid MCDM approach for selecting the agile concept for instrument panel. The agility criteria were defined and a new model was formulated based on literature review and with the validation of industrial decision-makers. An accurate analysis by determining interdependent relationships within and among a set of agile criteria was found using fuzzy ANP and fuzzy DEMATEL. The best alternative for instrument panel was selected based on Fuzzy TOPSIS. A future research direction proposed by Büyüközkan and Cifci [3] was fulfilled for agile concept selection in this study. The case study was practically validated in the industrial scenario.

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