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APPLICATION OF ARAS FOR IDEA SCREENING PHASE OF NPD IN AUTOMOBILE INDUSTRY

A. N. Dessai
M. Caisucar
G. Usgaonkar
A. Salunke

Abstract:

New **P**roduct **D**evelopment (NPD) has become very important for automobile industry to survive in today's competitive market. The NPD process consist of several phases that an organisation employs in compound process of delivering new product to the market, involving research at all phases including product conception. The first phase of product development is idea generation phase. At idea generation phase new ideas crop up. All these ideas are not feasible, but few of them which are feasible involve qualitative as well as quantitative data. A study is done in an automobile manufacturing unit wherein decision to select best alternative among available alternative is carried out during idea generation phase of NPD. The data was collected from number of stakeholders having different technical/non-technical background and opinions, but having a equal say in decision making process. The opinion of each stakeholder is recorded in form of qualitative data and analysed during the study. This phase of decision making can be solved by **M**ulti-**A**ttribute **D**ecision **M**aking (MADM) methods. This paper shows the best alternative obtained through ARAS (**A**dditive **R**atio **AS**sessment). A 3-step approach has been used in this paper. Firstly, various important attributes and alternative from viewpoint of market are identified. Secondly criteria weightages and alternative rating are calculated from linguistic variables given by the decision makers. Finally, ARAS method is applied in the last step to get the best alternative. The alternative having highest score is taken as best alternative. All the decision makers were told to give their opinion in linguistic form and criteria weightages and alternative rating were calculated where equal weightages were given to each decision maker. Implications regarding idea generation phase, MADM, ARAS are discussed.

Keywords: *NPD, linguistic, MADM method, ARAS method*

1. INTRODUCTION

Today new product development has become a challenge due to the strong competition in the market. Development of new product ensures technologically updated product, aiming different segment and cannibalize an existing product. NPD has become more important for industries to cultivate, maintain and increase their market share by satisfying customer demand. The response collected from the decision maker is usually in the form of qualitative data. Since it is virtually based information, Qualitative data gives inexact values or characterizes but does not measure the attributes, characteristics, properties. Many a times data collected is improper and not validated which creates difficulties for analysis during early design stage. Improper data arise from lack of experience, wrong collection techniques and failure to follow correct data collection procedures. A rigid framework is required to enable the decision makers to identify critical factors for each phase of NPD process, and tools and techniques that can be used to convert and evaluate them further. Hence, new product development is a multi-attribute decision making problem and can be solved by various methods. In this paper a proposed method is shown where grey numbers are used to convert the data in quantitative form followed by application of ARAS method for ranking.

2. LITERATURE REVIEW

The ARAS (*Additive **R**atio **AS**sessment*) method was firstly introduced by Zavadskas and Turksis. In the literature there are many such implementations of ARAS method. Zavadskas and Turskis (2010) firstly introduced ARAS method and evaluated microclimate in newly built office rooms to propose this method. Zavadskas et al. (2010) selected the foundation instalment alternative for safe building with ARAS method [1]. Sliogeriene et al. (2013) made the analysis of Lithuania's energy generation technology [2]. Reza and Majid (2013) ranked the financial institutions with ARAS and ANP method on the basis of proposed criteria affecting customer's trust in online-banking [3].Kaklauskas et al.(2013) selected the best housing renovation project for standard five-story panel house built in Vilnius [4].Chatterjee (2013) considered the eight preference ranking-based methods (EVAMIX, COPRAS, COPRAS-G, EXPROM2, ORESTE, OCRA, ARAS and PSI) for decision making in flexible manufacturing applications [5]. Chatterjee and Chakraborty (2013) solved a gear material selection problem in a given manufacturing process with COPRAS and ARAS methods [6].V.kutut et al.(2014) showed assessment of alternative of historic building using model based on ARAS [7].Haralambopoulos, D.Polatidis (2003) proposed framework for renewable energy under group decision making [8]. Sarfaraz Hashemkhani Zolfan et al (2018) used stepwise weight assessment ratio method to determine weights of evaluation criteria and ARAS method for purchase housing problem .Shariati et al. (2014) proposed the fuzzy GARAS (Group ARAS) method for selection of best waste dump site in Ayerma phosphate mine in Yasouj, Iran [9].Ghadikolaei and Esbouei (2014) evaluated the financial performance of the industries in automobile and parts manufacturing industry that traded on Tehran Stock Exchange (TSE) [10]. Gezder, &Şengül (2015) have employed MADM tools and applications to solve area related problems such as energy, environment and sustainability

[11]. Roy (2005) has madeactive research and produced many theoretical and applied articles and books. Bouyssou et al. aimed at choosing among the objects, rank ordering them and sorting them into categories [12].Behzadian et al. demonstrated vitality of the field and reported several methods [13].köksalan, Wallenius, &Zionts (2011) provides a brief history of the development of MADM methods which briefly describes the development of the area from ancient to modern times [14].Saaty (1980,1996)published a detailed study on the analytic hierarchy process (AHP) and further development of the analytic network process (ANP) method [15].

3. METHODOLOGY

Data is collected from various decision makers which are in qualitative form. The decision makers were asked to give alternative rating and criteria weightages for each idea. This data is then converted into quantitative form using grey numbers. Further ARAS method is applied to this quantitative data to obtain the result.

3.1 Grey scale

Deng (1982) initiated the theory of Grey system. The systems which lack information, such as in terms of quantity, and behaviour document, are referred to as Grey Systems. The aims of Grey System theory are to provide technique, theory, notation and procedure for solving intricate system. The advantages of Grey numbers are that they can be used for decision making, forecasting, relational spaces mathematics and grey theory.

3.2 ARAS Method

This method both determines the performances of alternatives and compares scores alternatives with the ideal alternative. According to ARAS method, utility value which determines the relative efficiency of alternatives (ideas) is directly proportional to the values and weights of main criteria considered in the assessment. Follow the steps given below for application of ARAS:

Step 1: Identify the number of decision makers or stakeholders and generate the number of feasible alternatives, criteria should be chosen. Say i alternatives, j criteria and k decision makers.

Step 2: Data is obtained from the decision makers to give criteria weightages and alternative ratings in linguistic form.

Step 3: Use standard Grey numbers to convert the linguistic variables into quantitative form and get the averages for alternative rating and criteria weightages.

Step 4: Construct a decision table (decision matrix) for application of ARAS where A0 is the optimal solution.

$$X = [x_{ij}]_{mxn} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (i = 1,2 \ldots\ldots, m; j = 1,2, \ldots\ldots, n)$$

Where x_{ij} represents the value of i^{th} alternative on j^{th} criterion , m and n are the numbers of alternatives and criteria respectively.

Step 5: The decision matrix is normalised where beneficial criteria are normalized with linear normalization procedure as follows

$$x^*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (1)$$

Where x^*_{ij} is the normalized values with two stage procedure Non beneficial criteria are normalized by first taking reciprocal of each criterion with respect to all the alternative

$$x^*_{ij} = \frac{1}{x_{ij}} \quad (2)$$

In the next stage, the normalized values are then calculated as follows

$$R = [r_{ij}]_{mxn} = \frac{x^*_{ij}}{\sum_{i=1}^{m} x^*_{ij}} \quad (3)$$

Where r_{ij} is the normalized value obtained for non-beneficial criteria

Step 6: The normalized decision table is weighted as follows

$$D = [d_{ij}]_{m*n} = r_{ij*} w_{ij} \quad (4)$$

Where W_{ij} is the weight of j^{th} criteria and d_{ij} is the weighted normalized value

Step 7: The optimality function Si is determined for each alternative as follows

$$S_i = \sum_{j=1}^{n} d_{ij} \qquad (i = 0,1,2 \ldots\ldots, m; j = 1,2, \ldots\ldots, n)$$

Where S_i is the optimality values

Step 8: The degree of utility (U_i) for each alternative is calculated as follows:

$$U_i = \frac{S_i}{S_o} \quad (6)$$

Where U_i is the degree of utility and S_o is optimality value of optimal alternative.

3.3 Application

In this section, alternative evaluation during idea screening is determined using ARAS method. Based upon market scenario, the company had three new product ideas namely A1, A2, A3. The criteria which were taken into consideration to evaluate these ideas were Creativity (C1), Manufacturing (C2), Cost (C3), Regulatory requirement (C4), and sales(C5) and three decision makers were identified.

Step 1: Three decision makers (DM1, DM2, DM3). Five criteria's (C1, C2, C3, C4, C5) and three alternatives (A1, A2, A3) are identified.

Step 2: The three decision makers were asked to criteria weightages and alternative rating. (Refer table 1 and 2)

Table 1 Linguistic rating for weightages

CRITERIA WEIGHTAGES			
DATA	DMI	DM2	DM3
C1	VH	M	VH
C2	H	VH	L
C3	M	L	VH
C4	H	VL	M
C5	M	L	VH

Table 2 Linguistic rating for alternative

ALTERNATIVE RATINGS									
DATA	A1			A2			A3		
	DMI	DM2	DM3	DMI	DM2	DM3	DMI	DM2	DM3
C1	G	G	F	VG	G	P	G	G	F
C2	F	G	G	G	G	G	F	F	F
C3	G	G	G	G	G	G	G	F	G
C4	G	P	F	G	F	F	G	F	F
C5	VG	F	P	G	G	F	F	F	P

Step 3: The qualitative data of the decision makers is converted to quantitative data using grey numbers (refer table 3) and aggregate the criteria weightages and alternative rating (Refer table (4 and 5).

Table 3 Grey Rating for Linguistic Variable

CRITERIA		ALTERNATIVE		GREY NO
VERY LOW	VL	VERY POOR	VP	1-2
LOW	L	POOR	P	2-4
MEDIUM	M	FAIR	F	4-6
HIGH	H	GOOD	G	6-8
VERY HIGH	VH	VERY GOOD	VG	8-9

Table 4 Aggregation of criteria weights

	DM1	DM2	DM3	SUM	AVERAGE WEIGHT	WEIGHT
C1	8	4	8	20/3	7.33	0.25
	9	6	9	24/3		
C2	6	8	2	16/3	6.17	0.21
	8	9	4	21/3		
C3	4	2	8	14/3	5.5	0.19
	6	4	9	19/3		
C4	6	1	4	11/3	4.5	0.16
	8	2	6	16/3		
C5	4	2	8	14/3	5.5	0.19
	6	4	9	19/3		

Table 5 Aggregated table for alternative rating

	C1	C2	C3	C4	C5
A1	6.33	6.33	7	5	5.5
A2	6.16	7	7	5.67	6.33
A3	6.33	5	6.33	5.67	4.33

Step 4: Locate the optimal rating of each criteria and construct a decision table where A0 shows the optimal performance rating of + each criteria (refer table 6)

Table 6 Decision table (decision matrix)

Criteria type	max	max	min	max	max
	C1	C2	C3	C4	C5
A0	6.33	7	6.33	5.67	6.33
A1	6.33	6.33	7	5	5.5
A2	6.16	7	7	5.67	6.33
A3	6.33	5	6.33	5.67	4.33
SUM	25.15	25.33	26.66	22.01	22.49

Step 5: The decision table is normalized by using Eq. (1)-(3) and shown in table 7

Table 7 Normalized table

	C1	C2	C3	C4	C5
A0	0.25	0.27	0.26	0.25	0.28
A1	0.25	0.24	0.23	0.23	0.24
A2	0.24	0.27	0.23	0.26	0.28
A3	0.25	0.20	0.26	0.26	0.19

Step 6: The weighted normalized table is calculated by using Eq. (4) and shown in table 8

Table 8 Weighted normalized table

	C1		C2	C3	C4	C5
A0	0.062		0.056	0.049	0.040	0.053
A1	0.062		0.050	0.043	0.036	0.045
A2	0.060		0.056	0.043	0.041	0.053
A3	0.062		0.042	0.049	0.041	0.0361

Step 7: Calulate the optimality function value Si by summing up the values against each criteria by using Eq.5 (refer table 9)

Table 9 Optimality function values

	S_i
A0	0.260
A1	0.236
A2	0.253
A3	0.230

Step 8: Utility degree of each alternative is calculated by using Eq.6 (refer table 10)

Table 10 Utility Degree values

	S_i	U_i
A0	0.260	1.00
A1	0.236	0.90
A2	0.253	0.97
A3	0.230	0.88

4. RESULTS:

Table 11 Final ranking

	S_i	U_i	Rank
A0	0.260	1.00	---
A1	0.236	0.90	2
A2	0.253	0.97	1
A3	0.230	0.88	3

It is revealed from the table that ranking order of automobiles for new product development can be represented as A2>A1>A3. It means that alternative 2 is the best option with 97% utility degree followed by alternative A1 and alternative A3 with 90% and 88% respectively.

5. SENSITIVITY ANALYSIS

Sensitivity analysis is a very useful technique used particularly to determine the impact of different values or weightages in this case on dependent variables. In this case sensitivity analysis is done on ARAS by changing the weights of each criteria one by one and at the same time keeping the other weights low. The highest rating that can be assigned is 8-9 and lowest is 1-2 (refer table 3). Sensitivity analysis shows Alternative 2 emerges out to be the best idea even with change of weightages except in case III which is cost and non-beneficial criteria favours Alternative 3 over Alternative 2 in ranking. The table shown below gives the final results obtained after sensitivity analysis. (refer table 12).

Table 12 Sensitivity Analysis

CASE	CRITERIA	A0	A1	A2	A3
I	C1(8-9) and C2, C3, C4, C5(1-2)	100	95.2663	**96.8836**	94.0828
II	C2(8-9) and C1, C3, C4, C5(1-2)	100	89.8595	**98.8606**	81.2761
III	C3(8-9) and C2, C1, C4, C5(1-2)	100	89.6672	93.1502	**94.195**
IV	C4(8-9) and C1, C2, C3, C5(1-2)	100	91.4004	**100**	95.9363
V	C5(8-9) and C1, C2, C3, C4(1-2)	100	88.2177	**98.8814**	77.9642
VI	C1, C2, C4, C5 (8-9) and C3 (1-2)	100	91.311	**99.5427**	86.2805

6. DISCUSSION

The necessity of new product development is crucial and undeniable which helps industries to identify its strength and weaknesses as well as recognize and upgrade the product. There are several approaches that has been used and advanced over the years and MADM is one of them. This method can be extended into fuzzy environment and ARAS-G to select the most appropriate option. The data can also be evaluated with fuzzy TOPSIS, fuzzy VIKOR and fuzzy ARAS methods and ranking can be seen.

7. CONCLUSION

In this paper MADM approach is described for new product development in an automobile industry using COPRAS grey scale and ARAS method. These approaches are chosen due to their suitability and effectiveness. The approach begins with identifying new ideas for product development and various criteria from which decision was taken. The decision-making process consists of three decision makers namely: Design Manager (DM1), Production Manager (DM2), and Marketing Manager (DM3). In the next step the three decision makers provide linguistic rating for criteria weightages and alternatives. These rating are converted into quantitative data using COPRAS-Grey scale. In the following step aggregate of these rating were taken to provide an overall assessment of alternatives against criteria. To this assessment ARAS was applied to get utility values and priority order of ideas. In this paper alternative 2 came up as the best idea followed by alternative 1 and alternative 3. An overall utility value of alternative is taken into consideration while ranking the alternative. The author has established the framework wherein there were limitation before in solving the MCDM problems involving only qualitative data. Decision makers have different levels of understanding of the data and interpret scales differently, and the complexity of rating scales varies with the number of points on the scale hence the aggregation procedure defined in the paper would help in structuring of any kind of data. Using these technique decision makers can prioritize alternatives that cannot be solved using common optimization models. The application of the neutrosophic sets in above kind of qualitative data of MCDM would be the state of the art.

REFERENCES

1. *Zavadskas and turskis, Multiple criteria analysis of foundation instalment alternatives by applying Additive Ratio Assessment (ARAS) method. Archives of Civil and Mechanical Engineering, Volume 10, Issue 3, pp. 123-141,2010.*

2. *Sliogeriene et al., Analysis and Choice of Energy Generation Technologies: The Multiple Criteria Assessment on the Case Study of Lithuania, Energy Procedia, Vol. 32, pp. 11-20,2013.*

3. *Sheikh Reza and Ameri Majid, Ranking Financial Institutions Based on of Trust in online banking Using ARAS and ANP Method, International Research Journal of Applied and Basic Sciences, Vol 6, pp.415-423,2013.*

4. *Kaklauskas et al., Knowledge-Based Model for Standard Housing Renovation, Procedia Engineering 57, pp.497 - 503,2013.*

5. *Prasenjit Chatterjee and Shankar Chakraborty, Flexible manufacturing system selection using preference ranking methods: A comparative study, International Journal of Industrial Engineering Computations,2013.*

6. *Prasenjit Chatterjee and Shankar Chakraborty, Material selection using preferential ranking methods, Materials & Design, Vol. 35, pp. 384-393,2012.*

7. *V.Kutut et al., Assessment of priority alternatives for preservation of historic buildings using model based on ARAS and AHP methods, Archives of Civil and Mechanical Engineering, Vol. 14, Issue 2, pp. 287-294,2014.*

8. *D.A.Haralambopoulos and H.Polatidis, Renewable energy projects: structuring a multi-criteria group decision-making framework, Renewable Energy, Vol. 28, Issue 6,pp. 961-973,2003.*

9. *Shahram Shariati et al., Proposing a New Model for Waste Dump Site Selection: Case Study of Ayerma Phosphate Mine, Engineering Economics, pp.410-419,2014.*

10. *Ghadikolaei and Esbouei, Applying Fuzzy MCDM for financial performance evaluation in Iranian Companies,*

Technological and economic development of economy, Volume 20(2), pp.274-291,2014.

11. *Gezder et al., Fuzzy TOPSIS method for ranking renewable energy supply systems in Turkey, Renewable Energy, Vol. 75, pp. 617-625,2015.*

12. *Denis Bouyssou, An axiomatic approach to non-compensatory sorting methods in MCDM, European Journal of Operational Research, Vol. 178, Issue 1pp. 217-245,2007.*

13. *Majid Behzadian, A state-of the-art survey of TOPSIS applications, Expert Systems with Applications, Vol.39, Issue 17, pp 13051-13069,2012.*

14. *Köksalan et al., Convex cone-based partial order for multiple criteria alternatives, Decision Support Systems, Vol. 51, Issue 2, Pages 256-261.2011.*

15. *Thomas L. Saaty, Decision making with the analytic hierarchy process, Int. J. Services Sciences, Vol. 1, No. 1,2008.*

AUTHORS

Amey Naik Dessai, Department of Mechanical Engineering, Goa College of Engineering, Goa,
Email ID : ameynaikdessai@gmail.com

Mahesh Caisucar, Department of Mechanical Engineering, Goa College of Engineering, Goa,
Email ID : maheshc@gec.ac.in

Gajesh Usgaonkar, Department of Mechanical Engineering, Goa College of Engineering, Goa
Email ID : ameynaikdessai@yahoo.in

Ajit Salunke, Department of Mechanical Engineering, Don Bosco College of Engineering, Goa
Email ID : ajs6@rediffmail.com